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THE OCCURRENCE OF CRETACEOUS SEDIMENTS IN SOUTH-WESTERN VICTORIA

By P. R. Kenley

[Read 9 April 1953]

Abstract

Dicotyledonous leaves occur in association with leaves of exclusively Mesozoic plants in a fossil flora collected from the Runnymede Formation at Killara Bluff, near Casterton. This flora indicates a Cretaceous age for the beds. The Runnymede Formation occurs at the top of lacustrine Mesozoic sediments (Merino Group) in the Killara Bluff area, and is unconformably overlain by marine sediments of Palaeocene or Lower Eocene age (Bahgallah Formation).

The stratigraphic relations of the Runnymede Formation are described; and the distribution, age, and lithology of the Merino Group in south-western Victoria are discussed. The Merino Group was formerly regarded as entirely of Jurassic age.

Introduction

Lacustrine mudstones and felspathic sandstones (arkoses) of Mesozoic age outcropping around Merino, Casterton, and Coleraine in south-western Victoria form one of the main occurrences of Mesozoic sediments in the State. Apart from small occurrences of Triassic sediments at Bacchus Marsh and Campbelltown, the Victorian Mesozoic deposits have generally been attributed to the Jurassic since about the year 1900, and Medwell (1954a) has recently shown that they are predominantly of Lower Jurassic age. Several accounts of the Jurassic rocks of the State (Skeats, 1935; Edwards and Baker, 1943; David and Browne, 1950) include brief descriptions of the Mesozoic deposits of the south-west. However, the presence of two angiosperm leaves among the fossil plants recently collected from Mesozoic sediments at Killara Bluff, seven miles south of Casterton, suggests that Cretaceous sediments occur in this area. Determinations of the complete fossil macroflora made by Miss L. M. Medwell (formerly of the School of Geology, University of Melbourne) confirm this conclusion, and show that these beds are probably of Lower Cretaceous age (Medwell, 1954b). This is the first record of Cretaceous rocks in Victoria, although David and Browne (1950, p. 514) have suggested that western Victoria was probably the site of a lake in Cretaceous time.

The Mesozoic sediments of south-western Victoria comprise a major lithological unit for which the term Merino Group (Hills, Teichert and Thomas, 1952) has been adopted. In this paper present knowledge of the Merino Group is reviewed, and new evidence relating to the age and stratigraphy of the upper part of the Group is brought forward.

Distribution and Thickness of the Merino Group

An outline of the approximate area occupied by Merino sediments is given in Fig. 1. The map is based on the Victorian Geological Survey eight miles to one inch geological map of the State (Murray, Stirling *et al.*, 1902), with amendments from the detailed mapping of Caldwell (1930-1932) and the more recent work of the Survey (1949-1952).


APPROXIMATE DISTRIBUTION OF THE MERINO GROUP
Scale of Miles
0 10 20 30
F × Fossil localities
• Bores C - Casterton M - Merino
Upper Cainozoic
Newer Volcanic
Lower Cainozoic
Mesozoic (Merino Group)
Acid & Intermediate Lavas
Palaeozoic
Comaum bore
Salt Creek
Dergholm
WARROCK
GLENELG
Roseneath
KANAWINKA
FAULT
DUNDAS
'Retreat'
Dunrobin
RIVER
Carapook
FOLLETT
Casterton
F1
C1
C2
Sandford
MUNTHAM
WANNON
Koroite
RIVER
Coleraine
Mt Koroite
Bahgallah Bluff
Bahgallah
Sandford Bluff
Winninburn
M3
Wannon
Bochara
F2
'Runnymede'
Landslip, F3 & 4
Killara Bluff
MOCAMBORO
M2
Road cutting
TAHARA
Merino
'Murndal'
KILLARA
SOUTH AUSTRALIA
Coastal plains
MYARING
STOKES RIVER
NORMANBY
WEECURRA FAULT
Jurassic (?)
GLENELG RIVER
CRAWFORD RIVER
Basaltic plains
Dartmoor
37°30'
38°0'
141°0'
141°30'
142°0'

Fig. 1

The main exposures are in the valleys of the Glenelg, Wannon and Stokes Rivers and their tributaries, the outcrops being distributed over a roughly triangular area the centre of which is in the vicinity of Merino. The interfluves in this area are generally tablelands where the Merino Group is capped by a thin deposit of lateritized Cainozoic sands and gravels. The laterites are fossil soils (Dunn, 1912, p. 113; Hills, 1939, p. 302; Blackburn and Leslie, 1949) which transgress the bedding in the Cainozoic sediments (Hills, 1939, p. 302) and therefore do not constitute a true stratigraphic rock unit. They have generally been referred to informally as the "Dundas laterites".

A fringe of marine Lower Tertiary sediments with a maximum thickness of about a hundred feet caps the Merino Group along the western edge of the triangle, which is bounded on this side by the Kanawinka and Weecurra faults (Boutakoff, 1952). These and associated faults bring the Merino Group against the thick Cainozoic sediments of the coastal plains of County Follett and County Normanby. In the south-east and east the Merino Group passes beneath Tertiary sediments and the Newer Volcanics of the Western District basaltic plains. Skeats (1935, p. 125) has suggested that it may be continuous beneath the basalts with the Mesozoic deposits of the Otways area, as fragments of "Jurassic" sediments occur among the ejectamenta of some of the Western District volcanoes. In the north and north-east the Mesozoic abuts unconformably on Palaeozoic sedimentary, metamorphic, and igneous rocks in County Dundas and the northern part of County Follett. The junction of the Merino Group with these older rocks outcrops in a line passing through Coleraine, Carapook and Retreat, which may in part mark the line of a fault or monoclinal flexure (see Structure). A small inlier of mica schists and gneisses containing veins of pegmatite occurs on the Wannon River at Winninburn, south of Coleraine.

The Merino Group presumably continues beneath the Cainozoic sediments to the south and south-west of the Kanawinka fault, but excepting outcrops in the Glenelg valley in the neighbourhood of Killara Bridge the only record of definite Mesozoic sediments in this region is from a bore at Robe (South Australia) in which they were first encountered at a depth of about 1,468 ft., and were still being drilled when boring ceased at 4,504 ft. (Ward, 1917, 1926). The outcrops in the bed of the Glenelg River shown as Jurassic on the Mines Department parish plan of Myaring (Kenny and McEachern, 1937) have now been shown to belong to the same formation as the "Oligocene" sands and ligneous clays of the Dartmoor area.

The Merino Group also extends beneath a cover of younger rocks to the north-west of the main triangular area and has been recognized in outcrops on Salt Creek, north of Dergholm (Caldwell, 1941); in samples from the original Comaum bore in Victoria (Allotment 50, Parish of Langkoop; approx. depth to Merino Group 575 ft.); and from the recent bore at Comaum in South Australia (Cookson, 1953. Bore in section 222, Hundred of Comaum; approx. depth to Merino Group 650 ft.).

Two bores in the main area pass through more than 900 ft. of Merino sediments (Merino No. 2, 909 ft.; Merino No. 3, 959 ft. Department of Mines, Victoria, 1898, p. 20; 1938, p. 28), and several others have penetrated over 500 ft. of these beds; but as yet Palaeozoic bedrock has not been intersected in bores within this area. The Merino No. 2, and Casterton Nos. 1 and 2 bores (Department of Mines, Victoria, 1938, pp. 34, 138), penetrating 909 ft., 758 ft. and 725 ft. of Merino sediments respectively, are situated on creek and river flats several hundred feet

below the level of the surrounding tablelands, and as dips in these areas appear to be low, the total thickness of the Merino Group at Merino and Casterton is at least a thousand feet and may be much greater.

Age of the Merino Group

Previous Age Evidence

Organic remains recorded from the Merino Group are few in number and come from widely scattered localities, some of which are difficult to locate precisely. The following occurrences are cited in the literature.

Mesozoic fossils in south-western Victoria were first discovered by Selwyn in April 1860 (Selwyn, 1862, p. 13). Selwyn found specimens of "*Taeniopteris Daintreei*" McCoy "in the banks of the Wannon opposite Mr. S. Winter's house, about six miles south-west of Bochara." Mr. Samuel P. Winter's homestead, "Murndal", was situated in the Spring Valley Pre-Emptive Right, Parish of Murndal, and it is probable that other records of "*T. Dantreei*" from "Murndal on the Wannon River" (McCoy, 1875, p. 16; Tenison-Woods, 1883, p. 117; Chapman, 1908, p. 215, etc.) also refer to this locality.

Later in the same year (1860) specimens of a new species of freshwater mussel were found by Mr. E. Dacomb in soft greenish-grey sandstone from a shaft put down near Coleraine by the Portland Coal Search Committee (Coleraine No. 1 shaft near Section 21, Coleraine Township; Selwyn, 1863, p. 17). The mussel was given the manuscript name of "*Unio dacombii*" by McCoy (Selwyn, 1861, p. 186; 1862, p. 13; 1867, p. 20) and its presence was considered to confirm a Mesozoic age for the beds. Unfortunately, although allusions were made to the forthcoming publication of figures and descriptions of this fossil (Selwyn, 1862, p. 13), these were apparently never published.

From a second shaft put down in search of coal in 1862 (Coleraine No. 2 shaft, Section 21, Coleraine Township; Selwyn, 1863, p. 17) Dacomb reported finding "*Taeniopteris Daintreei*" in the shales occurring between 17 ft. and 40 ft. In 1867 Selwyn (1867, p. 20) recorded the occurrence of "*Sphenopteris, Pecopteris, Zamites*, and *Taeniopteris*" in the beds intersected by these shafts. "*Taeniopteris spatulata* McClelland" from Coleraine, referred to by Chapman in 1908 (p. 215), probably also came from one of these shafts.

F. M. Krausé's catalogue of specimens sent to the 1886 Colonial and Indian Exhibition in London contained the following records (Krausé, 1886, pp. 78, 79):

"*Pecopteris australis*" and "*Taenipoteris Daintreei*" from calcareous shales on the Wannon River near Sandford; "*Taeniopteris Daintreei*" from ferruginous shales on the Glenelg River at Warrock; "*Taeniopteris, Sphenopteris*, etc." from sandy ferruginous shale on the Glenelg River at Roseneath; and "*Taeniopteris, Zamites* and *Zingophyllites*" from calcareous shale at Coleraine. Decomposed brecciated shale from a locality in a railway cutting on the left (east) bank of the Glenelg River at Casterton yielded "fragments of *Taeniopteris*, the homocercal tail of a ganoid fish (?leptolepis)," and "a large portion (neural plate) of the carapace of a cheIone". Of the Casterton specimens Krausé remarks: "These fossils tend to show that the Glenelg and Wannon beds are the lowest of the Mesozoic series of Victoria." The specimens in Krausé's collection were presented after the exhibition to the Museum of the Geological Society of Great Britain, London, and duplicates were stated to have been presented to the Mines Department, Melbourne.

Later (1894, p. 395; 1901, p. 15) Dennant recorded the cycad "*Otozamites*" from the Mesozoic at Mount Koroite, Coleraine (see also Hogg, 1899, p. 98; Skeats, 1909, p. 204; Summers, 1912, p. 139).

None of these early fossil records (1861-1894) are accompanied by figures or descriptions. The first formal descriptions of fossils from the Merino Group appeared in 1899 when T. S. Hall described the fossil fish *Psilichthys selwyni* Hall from Carapook, and *Leptolepis crassicauda* Hall from the railway cutting on the left bank of the Glenelg River at Casterton (Krausé's fossil fish locality). Hall regarded the fish as indicating a Triassic or Jurassic age for the beds. *Taeniopteris* sp. ind. and *Baiera* sp. were also described from the Carapook fossil fish beds (Dun, 1899).

Chapman (1908, p. 215) examined a large number of specimens of Victorian *Taeniopterii*, including specimens from Coleraine and Murndal, and concluded that all were variants of "*Taeniopteris spatulata* McClelland". In 1909 he recorded "*T. spatulata* var. *daintreei*", *Taeniopteris* sp., "*Sphenopteris ampla*", plant remains indet., and fragments of carbonized wood, from soft carbonaceous shales at Merino Creek, Merino (Chapman, 1909, p. 109).

Very little was added to our knowledge of the fossils of the Merino Group until the appearance of a paper by Cookson (1953) describing the microspore content of Mesozóic sediments from a bore at Comaum, South Australia (Section 222, Hundred of Comaum). Samples of grey mudstone taken from the bore at depths of 650 ft. and greater contain a Mesozoic microflora lacking angiosperm pollen. This microflora is regarded as indicating a Jurassic age.

Medwell (1954a) has recently reviewed the flora of the Victorian Jurassic, and refers most of the recorded species of *Taeniopteris* to *T. spatulata* Oldham and Morris (non McClelland); and of *Sphenopteris* to *S. hislopi* Oldham and Morris. From collections in Victorian museums she identifies *Ginkgoites australis* (McCoy) Florin, and *Taeniopteris spatulata* from Murndal; *T. spatulata* and *Sphenopteris hislopi* from the Coleraine No. 1 shaft; and *T. spatulata* from the Coleraine No. 2 shaft.

The stratigraphic positions of most of these localities cannot be ascertained at present, but as the localities are widely spaced, considerable thicknesses of beds may intervene between the various fossil horizons. In addition, many of the fossil assemblages are small and inconclusive as to age, so that the beds at only a few localities can be regarded as of proved Jurassic age. Nevertheless, approximate equivalence of age of the Mesozoic sediments throughout the State (excluding the Triassic of Bacchus Marsh and Campbelltown) has been generally assumed, and determinations based chiefly on fossil collections from localities in the South Gippsland area (reviewed Skeats, 1935, p. 126; Edwards and Baker, 1943, p. 214) have in general favoured a Jurassic age. Medwell (1954a) places most of the beds in the Lower Jurassic. In view of the occurrence of Cretaceous sediments in the Merino Group these correlations of age over great distances and thicknesses of beds must be regarded as tentative only.

New Age Evidence

Fossils

In the course of reconnaissance mapping carried out during May 1951 at Killara Bluff, seven miles south of Casterton, well-preserved fossil leaves were found in mudstones at two horizons near the top of the Merino Group (see Table 1)

TABLE 1.—*The succession at the Killara Bluff landslip (see Plate 1)*

Era	Age	Group	Rock Unit	Lithology and Typical Fossils	Thickness (member)	Thickness (unit)
CAINOZOIC	Holocene		Soil	Red-brown loam with abundant buckshot gravel in the B horizon.		1′ 6″
CAINOZOIC	Lower Pliocene (?)			Massive, yellow-brown quartz sand, traversed by numerous irregular veins of limonite. Impersistent bands of coarse quartz sand and lenses of conglomerate (containing pebbles of quartz, of the Bahgallah Formation, and of the Merino Group; and polished black ferruginous(?) nodules) occur at and near the base.		12′
			UNCONFORMITY			
CAINOZOIC	Lower Eocene and/or Palaeocene		Bahgallah Formation	Yellow-brown to brown granular clays, sandy clays, and sands (oxidized glauconitic sediments) with occasional beds of white sandy silt. Shelly fossils include: *Nuculana paucigradata*, *Cucullona psephea*, *Eotrigonia* sp., *Lahillia australica*, *Panopea* sp., *Aturoidea distans*, etc.	22′	53′
				Brown sands, coarse sands ('grits'), and occasional thin bands of gravel; with interbedded white to grey micaceous sandy silts. A 10 in. bed of fine conglomerate (containing pebbles of quartz and Runnymede Formation(?); fragmentary corals, pelecypods, and fossil wood) occurs about 6 in. from the base. Fragmentary marine shells and *Callianassa* burrows also occur in the upper part of this member.	31′	
			UNCONFORMITY			
MESOZOIC	Lower Cretaceous	MERINO GROUP (upper part)	Runnymede Formation	Blue-grey to white laminated, generally non-fissile mudstones (claystones and siltstones) with a few thin beds of friable, fine-grained felspathic sandstone. Fossil flora (F4) includes *Phyllopteroides lanceolata*, *Sphenopteris* cf. *S. burrumensis*, and dicotyledonous leaves. One specimen of fresh-water pelecypod (undet.) recorded.	24′	65′
				Light-grey to white friable, fine-grained, felspathic sandstone, with interlaminated mudstone in the upper 12 feet. Cross-bedded in the lower part of the member. Rounded pebbles of mudstone occur sporadically.	41′	
			DISCONFORMITY			
MESOZOIC	Upper Jurassic (?)	MERINO GROUP (upper part)	Mocamboro Member	Blue-grey to white laminated non-fissile mudstones (claystones and siltstones) and dark-grey to reddish-brown carbonaceous mudstones. Fossil flora (F3) includes *Phyllopteroides dentata*, *P. expansa*, *Taeniopteris spatulata*, etc. Vertical and sub-vertical root-like casts common.		24′ +

by Mr. D. Spencer-Jones and the writer, and were submitted for examination to Miss L. M. Medwell. Later (October 1951) collecting by Mr. A. N. Carter and the writer led to the discovery by Mr. Carter of a dicotyledonous leaf in the higher mudstone horizon (Runnymede Formation). Miss Medwell has since recognized a fragment of another angiosperm in the original collection and has described the flora of these beds in detail (Medwell, 1954b). Angiosperms have not previously been recorded from the Victorian Mesozoic.

The association of undoubted dicotyledons with typical Mesozoic leaves such as *Phyllopteroides* Medwell spp. (= *Phyllopteris* Walkom) and *Sphenopteris* cf. *S. burrumensis*, in Merino beds which unconformably underlie marine sediments assigned (Kenley, 1951) to the Palaeocene or Lower Eocene, points to a probable Cretaceous age for these beds. In other parts of the world the earliest records of definite angiosperm leaves are from Lower Cretaceous (Aptian) rocks (Berry, 1911; Ball, 1937; Walkom, 1919, etc.), although several authors draw attention to the advanced stage of specialization in described Lower Cretaceous forms, and the probability that they had a long developmental history.

The following determinations of new collections of fossil plants from Merino beds have been made by Miss Medwell (1954 a, b):

F1. Locality: Railway cutting, east side of Glenelg River, Casterton (fossil fish locality of Krausé and Hall). Latitude 37° 35′ 35″ S., Longitude 141° 24′ 42″ E.

Sphenopteris hislopi Oldham and Morris
Taeniopteris spatulata Oldham and Morris
Ginkgoites australis (McCoy) Florin
Brachyphyllum gippslandicum McCoy

Age: Lower Jurassic.

F2. Locality: Cliff section, Allotment 29A, Parish of Bahgallah. Lat. 37° 39′ 54″ S., Long. 141° 18′ 15″ E.
Horizon: About 10 feet from the top of the section.

Phyllopteroides expansa (Walkom) Medwell
P. dentata Medwell
?*Czekanowskia*

Age: ?Upper Jurassic.
Remarks: This flora is compared with F3.

F3. Locality: Scar of large landslip, Killara Bluff; Allotment 4, Section A, Parish of Killara. Lat. 37° 40′ 53″ S., Long. 141° 21′ 6″ E.
Horizon: Mocamboro Member (see Table 1).

Phyllopteroides dentata Medwell
P. expansa (Walkom) Medwell
Taeniopteris spatulata Oldham and Morris
Sphenopteris sp.
Brachyphyllum sp.

Age: Upper Jurassic or Lower Cretaceous.

Remarks: This flora is poor in genera and species, and leaf impressions of *Phyllopteroides* predominate.

F4. Locality: Same as F3.

Horizon: Mudstone member of the Runnymede Formation (see Table 1).

Phyllopteroides lanceolata (Walkom) Medwell
Sphenopteris cf. *S. burrumensis* Walkom
?*Czekanowskia*
Phoenicopsis elongatus (Morris) Seward
Araucarites cutchensis Feistmantel
Angiosperm
?Angiosperm

Age: Lower Cretaceous. This flora is compared with the floras of the Burrum Series and Styx River Series of Queensland.

Remarks: Leaf impressions and other plant remains are abundant in these mudstones and further careful collecting should add to the flora. Fragments of a freshwater pelecypod have also been found in these beds.

Stratigraphy of the Upper Part of the Merino Group

The beds containing the Upper Jurassic and Lower Cretaceous floras (F3 and F4) are exposed in the scar of a large landslip near the western end of Killara Bluff, and are stratigraphically the highest representatives of the Merino Group yet recognized (see Table 1).

Mocamboro Member. The older flora (F3) was collected from bluish-grey to white mudstones near the base of the landslip scar. These mudstones are part of a formation which is incompletely exposed and cannot be precisely defined at the present time. For the purpose of reference they are tentatively given the name of Mocamboro Member, after the neighbouring parish of Mocamboro.

Leaf impressions are common in these beds, and *Phyllopteroides* leaves have been found to within half an inch of the contact with the overlying felspathic sandstone which forms the lower part of the Runnymede Formation. The mudstones are generally thinly laminated, but tend to break with a conchoidal fracture, making collection of complete specimens of the fossil leaves difficult. Pieces of carbonized wood and other plant fragments abound, and in some beds the carbonaceous material imparts a reddish-brown colour to the rock. Vertical and sub-vertical casts of root-like structures ranging from fine threads to half an inch in diameter also occur in the mudstones, but are truncated at the contact with the overlying sandstones.

The Mocamboro Member-Runnymede Formation contact is marked by a thin deposit of limonite and cuts across the laminations and beds in the Mocamboro mudstone at a low angle, although dips in the two formations are very close. Small cracks (?mud cracks) in the top four inches of the Mocamboro mudstone are filled with felspathic sand containing angular fragments of mudstone apparently derived from the Mocamboro Member. The evidence suggests that the Mocamboro mudstones were exposed at the surface for a brief period whilst they were still in an unconsolidated condition. Mud cracks were developed, and vegetation (presumably swamp plants) was probably established before further inundation, accompanied by some contemporaneous erosion, initiated the Runnymede sedimentation. The Mocamboro Member-Runnymede Formation contact is therefore best regarded as a disconformity, and as the Mocamboro Member is probably of Upper Jurassic age and the Runnymede Formation of Lower Cretaceous age

(Medwell, 1954b), this disconformity has been taken as marking the Jurassic-Cretaceous boundary. The break in sedimentation may indicate that small-scale earth movements occurred in south-western Victoria at about the time of the epi-Jurassic folding in New Zealand.

Runnymede Formation. The Mocamboro Member is disconformably overlain by about 40 feet of light-grey to white, friable, fine-grained, felspathic sandstone (arkose). Much of the sandstone is laminated horizontally, but in the lower part of the bed cross-bedding is prevalent. Rounded mudstone pebbles are distributed sporadically through the sandstone. Towards the top this sandstone grades upwards through a zone of interbedded thin sandstone and mudstone beds into blue-grey to white laminated mudstones which bear a strong lithological resemblance to the mudstones of the Mocamboro Member. The mudstones comprise soft claystones and siltstones, and occasional beds of friable fine-grained felspathic sandstone. Some of the beds show small-scale cross-bedding and slump structures. Plant fragments, many of which are carbonized, are present throughout the strata; but well-preserved leaf impressions are practically restricted to a few horizons in the mudstones.

This sequence of beds overlying the Mocamboro Member forms a well-defined unit which has been named the Runnymede Formation after Runnymede Station, in which the type section occurs (scar of large landslip, Killara Bluff; Latitude 37° 40′ 53″ S., Longitude 141° 21′ 6″ E.).

Lithologically the Runnymede Formation and Mocamboro Member are similar to the Merino Group beds occurring lower in the same section and in other parts of the area; and in the field it is clear that all of these beds belong to the same rock group. A sharp lithological break occurs at the unconformable contact of the Runnymede Formation with the overlying marine Tertiary sediments of the Bahgallah Formation.

The Runnymede and Mocamboro beds can be traced for short distances to the east of the large landslip at Killara Bluff, and to the north in the parish of Bahgallah. Their relations to the undoubted Jurassic beds of the Casterton railway cutting are not known accurately, but they are probably several hundred feet stratigraphically higher in the sequence.

In general, however, exposures of the Merino beds are small, isolated, and of small vertical extent, and it is doubtful if an acceptable sub-division of the greater part of the Group will be possible without extensive boring. The occurrence of Lower Jurassic, Upper Jurassic (?) and Lower Cretaceous sediments in the Merino Group indicates that the Mesozoic section in south-western Victoria is more complete than was previously recognized.

Stratigraphic Relations of the Merino Group

At the north-eastern edge of the main area the Merino beds rest with angular unconformity on Palaeozoic (?Cambrian to Upper Carboniferous-Lower Permian) sedimentary, metamorphic and igneous rocks (Krausé, 1886, pp. 79, 80; Dennant, 1885-6, p. 102; Stirling, 1898, Sect. 5; Fenner, 1918), and fine conglomerates containing pebbles of some of these older rocks are locally developed near the base of the Group.

In the scar of the large landslip at Killara Bluff the Runnymede Formation at the top of the Merino Group is overlain with minor intersection of the beds by the basal ferruginous sand and fine conglomerate ("gravel") of the Bahgallah

Formation (Table 1; Pl. 1, fig. 3). The conglomerate is about 10 in. thick and is situated about 6 in. from the contact. It consists chiefly of rounded quartz pebbles (up to 1 in., but mostly $\frac{1}{4}$-$\frac{1}{2}$ in. in diameter) and contains small pebbles of laminated light-blue mudstone which are probably derived from the Runnymede Formation. Poorly preserved corals and pelecypods in the conglomerate indicate that marine conditions obtained from the very beginning of Bahgallah sedimentation. The basal conglomerate is surmounted by ferruginous sands and grits with intercalated micaceous sandy silts and occasional thin gravel bands. These in turn grade upwards into ferruginous sands and granular clays, in which the fossils *Nuculana paucigradata* F. A. Singleton, *Cucullaea* (*Cuculloma*) *psephea* F. A. Singleton, *Eotrigonia* sp. nov., *Lahillia australica* F. A. Singleton, *Panopea* sp., *Aturoidea distans* Teichert, etc., have been found, indicating a Palaeocene or Lower Eocene age for the beds (Kenley, 1951). Bahgallah beds in an unoxidized condition have recently been found in the bed of the Glenelg River downstream from Killara Bridge, where they are glauconitic sands (greensands), and clays.

The Merino Group-Bahgallah Formation contact is exposed in at least two other places in this area. One of these is at the western extremity of the Bahgallah Bluff (Allotment 37A, Parish of Bahgallah), on the north side of the Glenelg River, where the relations are essentially the same as at Killara Bluff; and the other is about 11 chains south-west of Runnymede Homestead where the uppermost Merino beds are friable felspathic sandstones. At each of the three localities the two formations have similar low dips, and weathered zones or channels in the surface of the Merino sediments appear to be absent. Well-preserved fossil leaves have been found about a foot below the unconformity at Killara Bluff. However, the presence of small pebbles of the Runnymede Formation in the basal conglomerate of the Bahgallah Formation indicates that a period of erosion intervened between the deposition of the uppermost beds of the Runnymede Formation and the lowest beds of the Bahgallah Formation. As the date of uplift of the Runnymede Formation is not known precisely, the duration of this period of erosion in south-western Victoria cannot yet be ascertained.

Upstream from the Killara Bluff landslip the Bahgallah beds are unconformably overlain by the bryozoal limestones of the Sandford limestone (Janjukian), at the base of which is a well-defined phosphatic nodule bed. Although these limestones appear to dip concordantly with the underlying Bahgallah Formation, mapping has shown that the contact is an irregular surface. Further upstream these limestones locally overlap the Bahgallah Formation and rest directly on the Merino Group at Sandford Bluff and Roseneath.

Between Casterton and Coleraine the Merino Group is immediately overlain by the thin Cainozoic sediments which bear the fossil lateritic soils of the tablelands (Hills, 1939, p. 302; Blackburn and Leslie, 1949, p. 5). The age of most of these Cainozoic sediments has not yet been established.

Lithology of the Merino Group Sediments

The principal lithological types in the Victorian Jurassic sediments have been described in detail by Edwards and Baker (1943). The sediments of the Merino Group consist chiefly of interbedded mudstones and medium- to fine-grained felspathic sandstones (arkoses). Mudstones are the predominant rock type (cf. Dunn, 1912, p. 114; Edwards and Baker, 1943, p. 198), but owing to the prevailing softness of the beds the proportion of mudstone present tends to be somewhat

exaggerated in field observations. The mudstones are frequently carbonaceous and contain occasional seams of impure black coal ranging from thin films to about two feet in thickness. Comminuted plant remains, many of which are carbonized, are present throughout the beds.

The sandstones are generally a dark greenish-grey in colour when fresh, but weather rapidly to a light greenish-grey, light brown, or ash-grey on exposure at the surface. The mudstones show a similar change from blue-grey (fresh) to buff or white on weathering. The unweathered sandstones owe their colour to the abundant chlorite cementing the detrital constituents of the rock (Edwards and Baker, 1943, p. 200). Notwithstanding this chlorite cement, the Merino sediments are generally less lithified than the Jurassic sediments in other parts of the State, and many of the sandstones are friable even when apparently fresh. The chlorite cement is replaced by secondary carbonate in some of the sandstone beds and in the 'cannonball' concretions (cf. Edwards and Baker, 1943). Pyrite is occasionally present in the sandstones (Selwyn, 1867, p. 17), and crystals up to half an inch in diameter were present in percussion drill chippings from a depth of about 300 feet in a bore at the Merino Consolidated School (Allotment 5, Section 111, Parish of Merino).

Intraformational breccia beds 6 in. to 1 ft. 6 in. thick containing pebbles of mudstones and sandstone, and some, fragments of coalified wood, have been observed at Casterton and Tahara. Isolated mudstone pebbles in some of the sandstones were probably also formed by contemporaneous erosion (cf. Edwards and Baker, 1943, pp. 212, 213). Small pebble lenses comprising pebbles of quartz, slate, and spotted slate (comparable with slates in the Dunrobin area) occur in sandstones in the cliff sections west of the Runnymede Homestead. Conglomerates have been recorded from bores at Merino and Muntham (Department of Mines, Victoria, 1938; Merino No. 7, pp. 41, 42; Muntham No. 1, p. 29), and beds of fine conglomerate containing pieces of carbonized wood, and pebbles of reef quartz, slate and sandstone, occur near the base of the Group at Nangeela, four miles north-north-west of Dunrobin. The pebbles are derived from the underlying Ordovician (?) bedrock.

The sandstone forming the lower part of the Runnymede Formation appears to be fairly representative of the Merino Group sandstones and conforms in most respects with the generalized descriptions of the Victorian Jurassic arkoses given by Edwards and Baker (1943). In thin section it is seen to consist of sharp, angular grains of quartz and acid felspar, flakes of biotite, and abundant subrounded to rounded rock fragments (mostly of intermediate (?) lava). These grains are cemented by pale-green chlorite which makes up about 25 per cent of the rock. The felspar grains are generally clear and consist predominantly of orthoclase together with a little oligoclase. On size analysis the sand grains in a typical specimen were found to range in size from about 1·5 mm. down to the lower limit of the sand size range (0·06 mm.), but 62 per cent of the grains were between 0·4 and 0·15 mm.

Sedimentary Structures

Cross-bedding is common in the sandstones and is also present on a small scale in the more fine-grained sediments. The sandstone beds are commonly lenticular, but in places individual beds appear to persist for some distance both parallel and normal to the strike. Channelling of the upper surface of beds has been observed in a number of localities.

As in the Jurassic rocks in other parts of the State, epigenitic "cannonball" concretions are common in the sandstones of the Merino Group. They are hard sub-spherical concretions ranging from about 6 in. to 3 ft. in diameter, in which the sand grains are cemented by secondary carbonate (cf. Edwards and Baker, 1943, p. 207). Cigar-shaped concretions, probably of a similar origin, are common in part of the Killara Bluff.

Conditions of Sedimentation

Edwards and Baker (1943) have shown that the Jurassic arkoses are of uniform composition throughout, and conclude that the various Victorian Jurassic deposits were originally laid down in the one lacustrine basin of deposition. As evidence of long stratigraphic breaks or marine intercalations is at present lacking, they consider that this basin persisted throughout the entire period of sedimentation. The lake waters are thought to have been generally shallow, subsidence having kept roughly apace with deposition. The prominent cross-bedding and frequent signs of contemporaneous erosion in the sediments are taken to indicate that strong currents were prevalent and that fluctuations of water level probably occurred which may at times have exposed the lake floor.

Conditions do not appear to have been generally suitable for the growth of plants within the lake waters, and plant debris in the sediments is almost entirely of drift origin (Edwards and Baker, 1943, p. 214); but the presence of fossil rootlets in the Merino Group at Killara Bluff (Mocamboro Member) and in mudstones exposed in a road cutting about one mile north-east of Merino on the Coleraine-Merino road (east side of Allotment 22A, Merino Township) indicates that at certain times plants grew *in situ* within the lake area in the south-west. This implies the existence, at least temporarily, of shallow water or terrestrial conditions. Sand-filled cracks (?mud cracks) at the top of the Mocamboro Member also indicate temporary exposure of the sediments at the surface. From the small outcrops available it is difficult to determine whether these features are due to small fluctuations of water level in the vicinity of the lake edge, or to the more general effects of earth movements.

The abundance of fresh angular felspar in the arkoses, and the presence of well-preserved remains of fragile plants in some of the mudstones indicate that the sediments were deposited rapidly (Edwards and Baker, 1943, p. 220). Vigorous erosion of the Mesozoic terrain and subsequent rapid deposition of detritus in the adjoining lake gave rise to the beds of arkose and occasional lenses of conglomerate; but as mudstones are the dominant lithological type in the south-west, it seems that sedimentation was less rapid in this part of the State than elsewhere in the Mesozoic sedimentary basin.

Structure of the Merino Group Area

The beds of the Merino Group are generally flat-lying or gently dipping; but locally the dips attain values of up to 15°. The higher dips are generally thought to be associated with faults (Skeats, 1935, p. 126); but because of the poor exposures, faults without topographic expression at the present time are rarely observed. Dips in the Runnymede Formation at Killara Bluff are very low and probably do not exceed 3°.

A description of the structural pattern of south-western Victoria has been given by Boutakoff (1952), and most of the faults shown in the map (fig. 1) are based

on his work. In addition to the faults he describes, there may also be a fault or monoclinal flexure along part of the north-east side of the triangle of Merino Group sediments, where the Merino strata abut on the complex of Palaeozoic rocks to the north. Dunn (1912, p. 114) observed that the Jurassic beds do not "extend much to the north of a line drawn from Hamilton through Coleraine and on to Roseneath"; but the existence of a fault in this position was first postulated in manuscript by Beavis (1947). Beavis observed prevailing dips of 10°-15° N. in Merino beds at Coleraine, a short distance south of outcropping Palaeozoic granites. The tablelands are at markedly different levels on either side of this line—the more elevated tablelands of central Dundas (1,000 ft. to 725 ft. above sea level) occurring to the north, and the lower tablelands of southern Dundas and northern Normanby (650 ft. to 600 ft. and less) to the south. This difference of elevation probably indicates some post-'Dundas laterite' faulting or monoclinal warping; but may also be in part due to gentle upwarping along an east-west axis of the land surface in central Dundas, as suggested by Hills (1939, p. 302; 1940, p. 276).

Evolution of the Present Topography

The greater part of the triangular area of Merino sediments seems to have been above sea level since the time of the withdrawal of the Bahgallah seas, although the south-western and south-eastern flanks of the area were submerged at various times by the advances of later Tertiary seas. At the end of Kalimnan (Lower Pliocene) time there existed a remarkable plain surface in the south-west—a surface relieved only by small isolated residual highlands of resistant rocks (e.g. Dundas Ranges and Mount Cavendish). A veneer of Cainozoic sands and gravels covered much of the plain area, and lateritic soils 10-15 ft. thick (the "Dundas laterites") were formed in these sands over most of the land areas which included County Dundas, the northern part of Counties Follett and Normanby, and adjoining areas in Victoria and South Australia.

The presence of a fossil tortoise which Chapman (1919, p. 12) refers "with some reservation" to the Murray River tortoise, *Emydura macquariae* (Gray), in an ironstone from Carapook has been interpreted as indicating that communication with the Murray by a dominantly fresh-water route was possible up to a comparatively recent time, and that therefore uplift of the Dundas Tablelands is of "fairly recent date" (Hills, 1939, p. 302). However, it seems probable that some of the fault scarps, such as those of the Kanawinka and Weecurra faults, were already in existence in Upper Pliocene time, as these appear to have formed the coastline in the Werrikooian sea (Boutakoff, 1952, p. 6). It therefore appears that the initial breaking up of this plain surface commenced in epi-Kalimnan time (cf. Hills, 1934, p. 166; 1940, pp. 274, 276; Boutakoff, 1952, p. 24) with the formation of an open system of fault blocks bounded by faults of small post-Kalimnan vertical displacement.

Deep valleys were carved in the vicinity of Wannon before extrusion of the Newer Basalts. Basaltic effusions, faulting and warping movements continued intermittently through late Pliocene to Pleistocene and Recent time (Hills, 1934, 1940; Boutakoff, 1952). The rejuvenated streams cut back rapidly from the epi-Kalimnan and younger fault scarps into the upfaulted blocks and quickly established deep gorge-like valleys. In the Merino Group area these valleys were rapidly widened by undercutting of the hard laterite capping and landslipping, thus reducing the size of the tableland interfluves until at present in some places only

small remnants of the original land surface remain. This process of dissection of the tablelands has progressed to a stage of late youth (Hills, 1939, p. 302; 1940, p. 261).

Palaeogeography

The Runnymede Formation has been traced for only short distances and its total distribution cannot at present be assessed. It may represent the deposits of a shrunken remnant of the Victorian Jurassic lake or of an extension of the great Cretaceous lakes of central Australia. However, strong post-Jurassic and pre-Maryborough (Upper Cretaceous) earth movements have not been recognized in Australia so that lakes may also have persisted from the Jurassic into the Cretaceous in other Mesozoic areas of Victoria and the south-eastern part of South Australia.

The probable widespread distribution of marine Palaeocene or Lower Eocene sediments in western Victoria (Baker, 1943, 1950; Kenley, 1951) establishes that downwarping or faulting of the southern part of the Upper Cretaceous terrain was initiated at the close of the Mesozoic era in this area as averred by Hills (1940, p. 271) and Baker (1943, p. 251).

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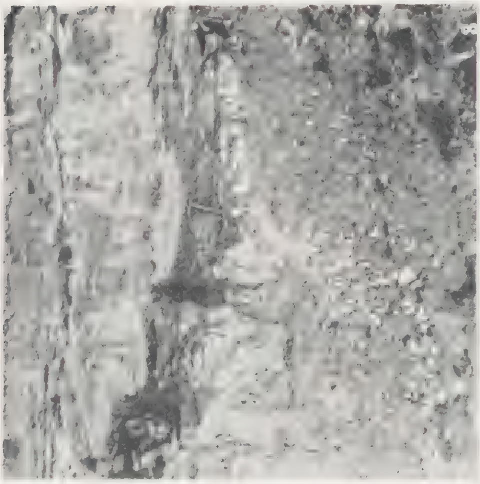
Explanation of Plate I

Fig. 1.—Killara Bluff from the north-east, looking across the valley of the Glenelg River. From left: Killara Bluff with the large landslip near its western end, the youthful scarp of the Kanawinka fault, the coastal plains of Follett and Normanby. The highest point on the Bluff is about 420 ft. above river level.

Fig. 2.—South face of the scar of the large landslip, Killara Bluff. The positions of stratigraphic breaks (see Table 1) are indicated by dashes. The total height of the cliff is about 160 ft.

Fig. 3.—The Runnymede Formation-Bahgallah Formation contact, Killara Bluff landslip scar. The trace of the contact is indicated by the hammer head, pick head, and right hand of figure. The pick handle is 3 ft. long.



2

FOSSIL PLANTS FROM KILLARA, NEAR CASTERTON, VICTORIA

By LORNA M. MEDWELL

[Read 9 April 1953]

Introduction

The plants described below were collected by Messrs. P. R. Kenley, A. N. Carter, and D. Spencer-Jones from the cliffs of the Glenelg River, at the scar of a large landslip in Allotment 4, Section A, Parish of Killara. An outline of the stratigraphy has been prepared by Mr. P. R. Kenley.

Plants occur at two distinct horizons. The lower plant bed—the Mocomboro mudstone member—consists of 24 feet of blue-grey to white laminated mudstones containing abundant plant impressions. This is separated by a disconformity from the overlying 41 feet of grey white felspathic sandstones and 23 feet of grey-blue to white mudstones which constitute the Runnymede Formation. The upper white mudstones of the Runnymede Formation also contain abundant plant remains. These are immediately overlain by an unconformity which separates these beds from the Tertiary.

The material consists of impressions only, and no details of cuticular structure are available, but the outline and venation of the leaves are well preserved.

Systematic Description of Species

A. PLANTS FROM THE MOCOMBORO MUDSTONE MEMBER, KILLARA

PTEROPSIDA
PLANTS OF UNKNOWN AFFINITY

Phyllopteroides n. gen.

Diagnosis: Leaves simple, linear-lanceolate; margins dentate or entire; midrib prominent, lateral veins leaving midrib at an acute angle and dividing dichotomously once or twice at varying distances from the margin, not anastomosing. Epidermal cells polygonal in outline.

Remarks: The leaves resemble *Phyllopteris* Walkom 1919 and *Linguifolium* Arber 1917. Some confusion has arisen regarding the genera *Phyllopteris* Brongniart, *Sagenopteris* Presl, and *Linguifolium* Arber, and the position has been discussed at length by Arber (1917, pp. 35-38) and by Walkom (1919, pp. 21-22). *Sagenopteris* Presl is distinctive in the possession of anastomoses of the secondary veins, and thus may be separated easily from the other two forms. *Phyllopteris* Brongniart is a true synonym for *Sagenopteris* Presl, as the term was originally applied wrongly to specimens of *Sagenopteris phillipsi* Brongniart and *Sagenopteris rhoifolia* Presl. The genus was founded under the misapprehension that the veins of these specimens did not anastomose, the mistake arising from inaccuracies in earlier illustrations.

Although specimens were found, many years later, which agree with the diagnosis given by Brongniart, it would be unwise to apply the old term to these

new forms. Arber proposed that the genus *Phyllopteris* should lapse, and instituted a new genus, *Linguifolium*, for leaves from the New Zealand Rhaetic of Mount Potts and ?Lower Jurassic of Malvern Hills (?Middle Jurassic, Edwards 1934). *Linguifolium* Arber is provisionally defined as follows:

"Leaves simple, large, usually tongue-shaped, gradually contracted at the base, margins entire. Midrib strong; lateral nerves arising at a very acute angle to the midrib, more or less arched, frequently dichotomising but not anastomosing." (Arber 1917, p. 35.)

In this opinion, Arber is supported by Jones and de Jersey (1947), who described and figured two species of *Linguifolium* from the Ipswich of Queensland. Specimens from the ?Rhaetic of Talcamavide and La Terna, southern Chile, and Tehuantepec, southern Mexico, were examined by Berry (1945), who also upholds the validity of the new genus. From Tasmania, Walkom (1925a) described *Linguifolium lillieanum* Arber and *Linguifolium diemenense* Walkom.

However, from the Burrum Series of Queensland, Walkom described specimens which are not identical with *Linguifolium* Arber as defined above. Walkom (1919) pointed out that the position of *Phyllopteris* was clearly defined by Saporta (1873), and thus no confusion need arise. He proposed that *Phyllopteris*, as used by Saporta, be applied to Australian plants including *Phyllopteris feistmanteli* Etheridge and the two species from the Burrum Series—*Phyllopteris lanceolata* Walkom 1919 and *Phyllopteris expansa* Walkom 1919. *Phyllopteris* was defined as follows:

"Leaves simple, more or less lanceolate, having a short petiole and entire or denticulate margin; median vein becoming thin towards the apex; secondary veins springing from the midrib at an acute angle, distinctly arched and dividing dichtomously, not anastomosing." (Walkom 1919, p. 22.)

I agree with Walkom that the definition of *Linguifolium* is not sufficiently wide to include the Australian forms cited above, but feel that a name other than *Phyllopteris* should be applied to them. I therefore propose to base a new genus, *Phyllopteroides*, on the material from Killara, and to suggest the inclusion in this genus of *Phyllopteroides lanceolata* (Walkom 1919), and *Phyllopteroides expansa* (Walkom 1919).

Phyllopteroides dentata n. sp.

Holotype: Geology Department, University of Melbourne, No. 2005.

Diagnosis: Leaf linear lanceolate, narrowing gradually towards the base, apex rounded. Margin dentate, dentation less marked at the apex. Midrib strong, straight, 1 mm. at the base, not persisting to the apex; lateral veins generally opposite, leaving midrib at an acute angle, arching, and bifurcating at varying distances from the margin; about four veins per tooth at margin.

Description: The specimens are preserved in a soft clay, and when examined under strong light, the outline of regularly polygonal epidermal cells may be seen. No material suitable for cuticular study was found.

The leaves range in length from 3 to 8 cm., averaging about 5 cm., and are from 0·5 to 1·5 cm. broad. They were very delicate, and in many cases were torn parallel to the secondary veins, giving an appearance similar to that of a *Sphenopteris* frond. The leaves always occur singly, and no good example of a leaf base was seen.

Phyllopteroides expansa Walkom 1919

1919. *Phyllopteris expansa* Walkom. *Qld. Geol. Surv. Publ., 263*: 24. Pl. 5, figs. 1, 2.

Larger, more delicate leaves occur with *Phyllopteroides dentata*, but as they are so abundant, and overlap considerably, it is difficult to be sure of their identity. No frond or pinna is seen, but the large torn leaves, with strongly arched veins, are probably identical with *Phyllopteris expansa* Walkom 1919. *Phyllopteris lanceolata* Walkom 1919 is a much neater leaf.

Taeniopteris spatulata Oldham and Morris 1863

(For synonymy see Medwell 1954.)

A small specimen of *Taeniopteris spatulata* occurs in the Mocomboro mudstone member at Killara. It is a very narrow leaf, 3 mm. wide, with a midrib of 1 mm. The secondary veins leave the midrib at right angles, and bifurcate at varying distances from the margin.

Sphenopteris sp.

A fragment of a frond resembling *Sphenopteris* bears alternate pinnules of rather subspathulate shape, narrowing to wedge shape at the base, with a finely serrate margin. The venation is typically Sphenopteroid.

This form is not the *Sphenopteris hislopi* Oldham and Morris 1863 of the Jurassic of Victoria, but is really too fragmentary to allow accurate specific identification.

Genus Indeterminate

Isolated leaves or pinnules of variable rounded or fan-shaped outline occur with the *Sphenopteris sp.* described above. These narrow abruptly at the base to a distinct petiole. There is no indication of a frond, although in one specimen the union of two petioles is seen.. The margin is finely serrate, and veins radiate from the base, bifurcating once or twice before reaching the margin. These leaves resemble an unlobed *Ginkgo*, but their affinities are unknown.

CONIFEROPHYTA
CONIFERALES
ARAUCARINEAE

Brachyphyllum sp.

Portion of a coniferous shoot, very imperfectly preserved, is probably a *Brachyphyllum*, but is insufficient for specific determination.

B. PLANTS FROM THE UPPER MUDSTONE HORIZON OF THE RUNNYMEDE FORMATION

PTEROPSIDA
PLANTS OF UNKNOWN AFFINITY

Phyllopteroides lanceolata Walkom 1919

1919. *Phyllopteris lanceolata* Walkom. *Qld. Geol. Surv. Publ., 263*: 22.

Isolated pinnules of broadly ovate outline, narrowing abruptly at the base to a short petiole, margin entire. The midrib does not persist to the apex, and secondary veins leave at an acute angle, arching to the margin, generally dichotomising.

These specimens bear a very close resemblance to *Phyllopteris lanceolata* Walkom 1919, which, Walkom states, is one of the commonest and most characteristic plants in the Burrum Series of Queensland. They are probably also present in the lower plant horizon at Killara, but the abundance of specimens in this bed makes identification of all fragments difficult.

It is to be stressed that the genus *Phyllopteroides* is an artificial one, as it is based wholly on leaf form and venation.

Sphenopteris cf. Sphenopteris burrumensis Walkom 1919

1919. *Sphenopteris burrumensis* Walkom. *Qld. Geol. Surv. Publ.*, 263: 19. Pl. 1, fig. 5.

Numerous fragments of *Sphenopteris* occur, which in pinnule shape appear close to the Burrum species, although no complete pinnae are found. Isolated pinnules vary in shape from the usual trilobed wedge shape to short rounded almost odontopteroid forms, and may most conveniently be linked with Walkom's species.

CONIFEROPHYTA

GINKGOALES

? Czekanowskia

A fragment of narrow, uninerved, dichotomising lamina may be placed either in this genus or in *Stenopteris*, but in the absence of cuticle is too small to be determined.

Phoenicopsis elongatus (Morris 1845) Seward 1903

(For synonymy see Walkom 1917b.)

1947. *Phoenicopsis elongatus* (Morris) Seward, Jones and de Jersey. *Qld. Univ. Publ.*, 111 (N.S.): 62.

The specimens from Killara consist of single, long, linear leaves, 5-6 mm. wide, tapering to a finely rounded apex; veins 9-10, parallel, not dichotomous; base of the leaf not seen.

The material most resembles *Phoenicopsis steenstrupi* Seward 1926, now placed by Florin (1936) in the genus *Culgoweria* on the basis of epidermal structure. As the cuticle of the Victorian form is unknown, it can not be placed in *Culgoweria*. *Culgoweria steenstrupi* occurs in the Cretaceous of Angiarsuit, Western Greenland.

Phoenicopsis elongatus has been described from many eastern Australian Mesozoic localities, and the Killara material is provisionally placed in this form genus and species.

CONIFERALES

ARAUCARINAE

Araucarites cutchensis Feistmantel 1876

Well preserved isolated cone scales of *Auraucarites* vary in shape from short, broadly winged, to longer and narrower forms, but this variation is not more than may be expected as resulting from different positions on the cone and from different degrees of development. All possess a single prolonged tip, and bear the impression of a single centrally situated seed. In some, the position of the ligule is well seen. Similar scales occur throughout the Mesozoic.

ANGIOSPERMOPHYTA

? Angiosperm

A portion of a leaf possessing a lobed orbicular outline, with deeply cordate base, is thought to be an *Angiosperm*. There is no midrib, two or three primary veins arising from the petiole and diverging into the lamina. The specimen is only a fragment, and is insufficient to ascertain the genus.

Angiosperm

A single specimen in the upper mudstone horizon of the Runnymede Formation is undoubtedly portion of an *Angiosperm* leaf. The leaf is incomplete, linear lanceolate, and almost 2 cm. wide at the broadest part. The midrib is distinct, and secondary veins are widely spaced and alternate. The preservation is not sufficiently good to determine the nature of the veins between these main veins.

The material at present available is not adequate for generic determination. Vegetative characters are notoriously inadequate as criteria of genera and species. Even combining these with the generally considered strongly diagnostic features of the stoma does not ensure accurate generic determination of *Angiosperms* (see Odell, 1932). Fruits, seeds, or pollen must be present if more than form genera are to be ascertained.

Age of the Flora

The flora described below is unlike any previously recorded from Victoria. The assemblage in the Mocomboro mudstone member differs from that in the Runnymede Formation, and although *Phyllopteroides* is common to the two collections, different species are present in each horizon.

A. The Mocomboro Mudstone Member

In the collection examined, by far the most abundant plant was *Phyllopteroides*, single overlapping leaves completely covering the bedding planes at intervals of a few millimetres. Plants related to *Phyllopteroides* are known only from the Mesozoic, Walkom recording "*Phyllopteris*" from the Burrum and Styx Series of Queensland, and the closely related *Linguifolium* Arber occurring in the Rhaetic and Jurassic of New Zealand, the Ipswich Series of Queensland, the Triassic of Tasmania, and the Rhaetic of southern Chile and southern Mexico.

Phyllopteroides dentata is present in the Victorian Lower Jurassic, being recorded from Allot. 49, Jumbunna, and from the Barrabool Hills. It is also found, with *Sphenopteris*, at Barangarook Creek, Colac. From several Jurassic localities, doubtful records have been made, the original specimens of which have not been traced, but the names and descriptions given them by earlier workers are strongly suggestive of their inclusion in *Phyllopteroides*. (See Medwell, 1954.)

Sphenopteris and *Brachyphyllum* are of little use in determining the age of the flora.

The narrow *Taeniopteris*—*Taeniopteris spatulata*—is a common and characteristic Jurassic plant, being recorded from Africa, India, New Zealand, New South Wales and Queensland, and is the most abundant plant in the Victorian Lower Jurassic. It is present in the Waikato Heads flora of New Zealand (which Arber, (1917) placed as Neocomian, but which Edwards (1934) suggests is Middle Jurassic), and has also been recorded from the Burrum and Styx Series of Queensland (Walkom, 1919).

Thus the flora of the lower plant horizon at Killara is of strongly Mesozoic aspect. The presence of *Taeniopteris spatulata* indicates Jurassic age. The complete absence of most of the plants common in the Victorian Lower Jurassic, the presence of only two small specimens of *Taeniopteris spatulata*, and the abundance of *Phyllopteroides*, which is extremely rare in the Lower Jurassic of Victoria and occurs in the Cretaceous of Queensland, suggest that the flora of the Mocomboro mudstone member may be placed in the Upper Jurassic.

B. Upper Mudstones of the Runnymede Formation

The flora of this bed is quite distinct from that of the Mocomboro mudstone member. *Phyllopteroides dentata*, which makes up the bulk of the material in the lower bed, is absent or very rare; *Phoenicopsis* and *Araucarites* make their appearance; and there is the notable occurrence of two *Angiosperms*.

The presence of these *Angiosperms* suggests that the age of the horizon is Cretaceous. Further evidence of Cretaceous age is given by the presence of *Phyllopteroides lanceolata* and *Sphenopteris burrumensis*, both of which also occur in the Burrum Series of Queensland, whose flora Walkom declares to be a typically Lower Cretaceous one, being homotaxial with the European Wealden and the Neocomian of North America. *Phyllopteroides lanceolata* is also present in the Styx Series, which Walkom places as somewhat younger than the Burrum Series, representing a higher stage in the Lower Cretaceous.

Phoenicopsis and *Araucarites* are of little use an indices of age. Cone scales of *Araucarites cutchensis* have a wide range in space and time, being recorded from beds ranging from Rhaetic to Cretaceous.

The age of the upper mudstones of the Runnymede Formation is therefore placed as Lower Cretaceous.

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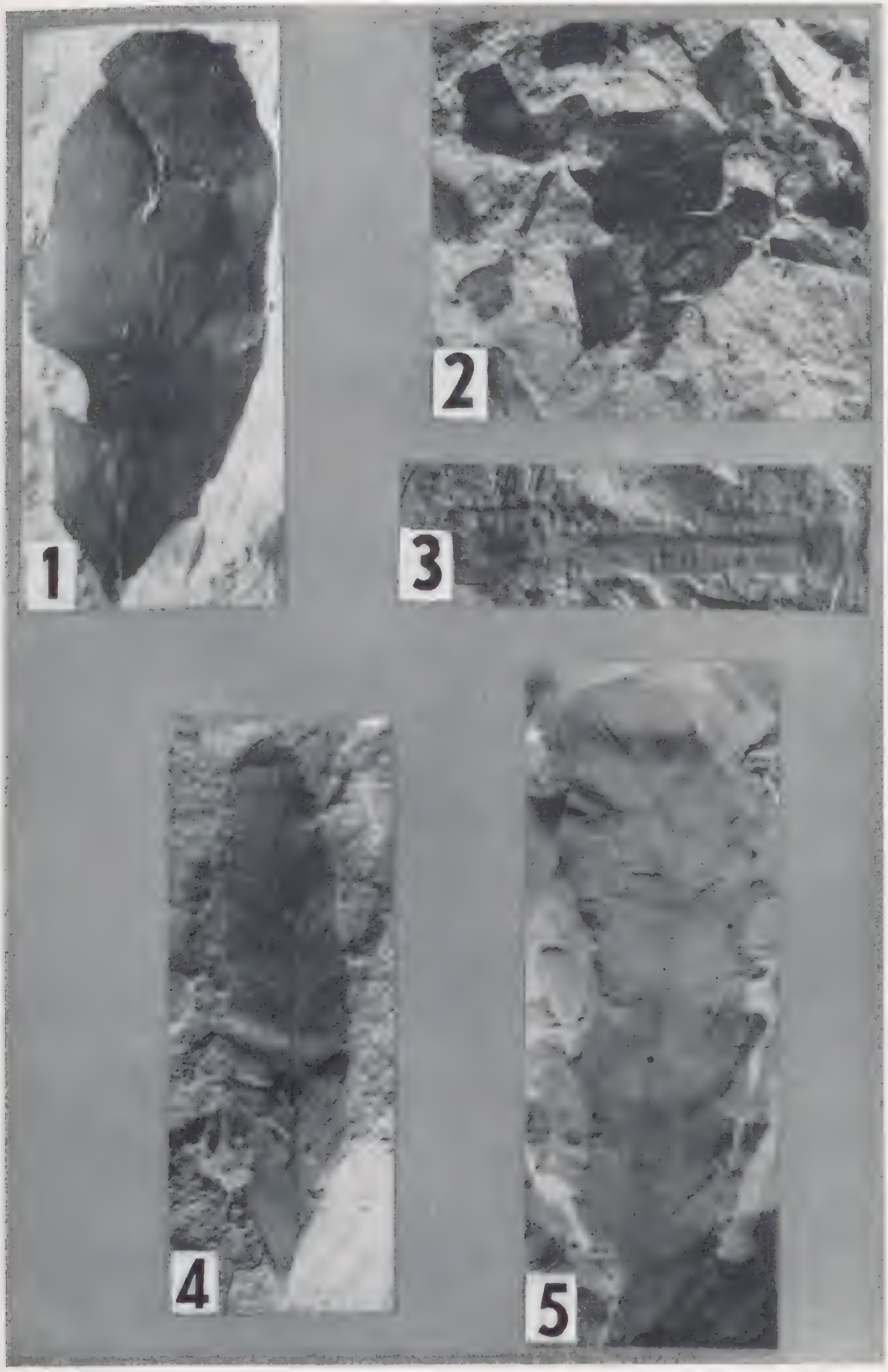
Explanation of Plates

PLATE II

FIG. 1.—*Phyllopteroides lanceolata* (Walkom 1919). Runnymede Formation. No. 2010.
FIG. 2.—Fan-shaped pinnules (see p.). Mocomboro mudstone member. No. 2017.
FIG. 3.—*Taeniopteris spatulata.* Mocomboro mudstone member. No. 2018.
FIG. 4.—*Phyllopteroides dentata,* n. sp. Mocomboro mudstone member. Holotype. No. 2005.
FIG. 5.—*Phyllopteroides dentata* n. sp. Mocomboro mudstone member, No. 2011.

PLATE III

FIGS. 6 & 7.—*Angiosperm.* Runnymede Formation. No. 2013.
FIG. 8.—? *Angiosperm.* Runnymede Formation. No. 2014.
FIGS. 9 & 10.—*Phoenicopsis elongatus.* Runnymede Formation. Nos. 2015, 2016.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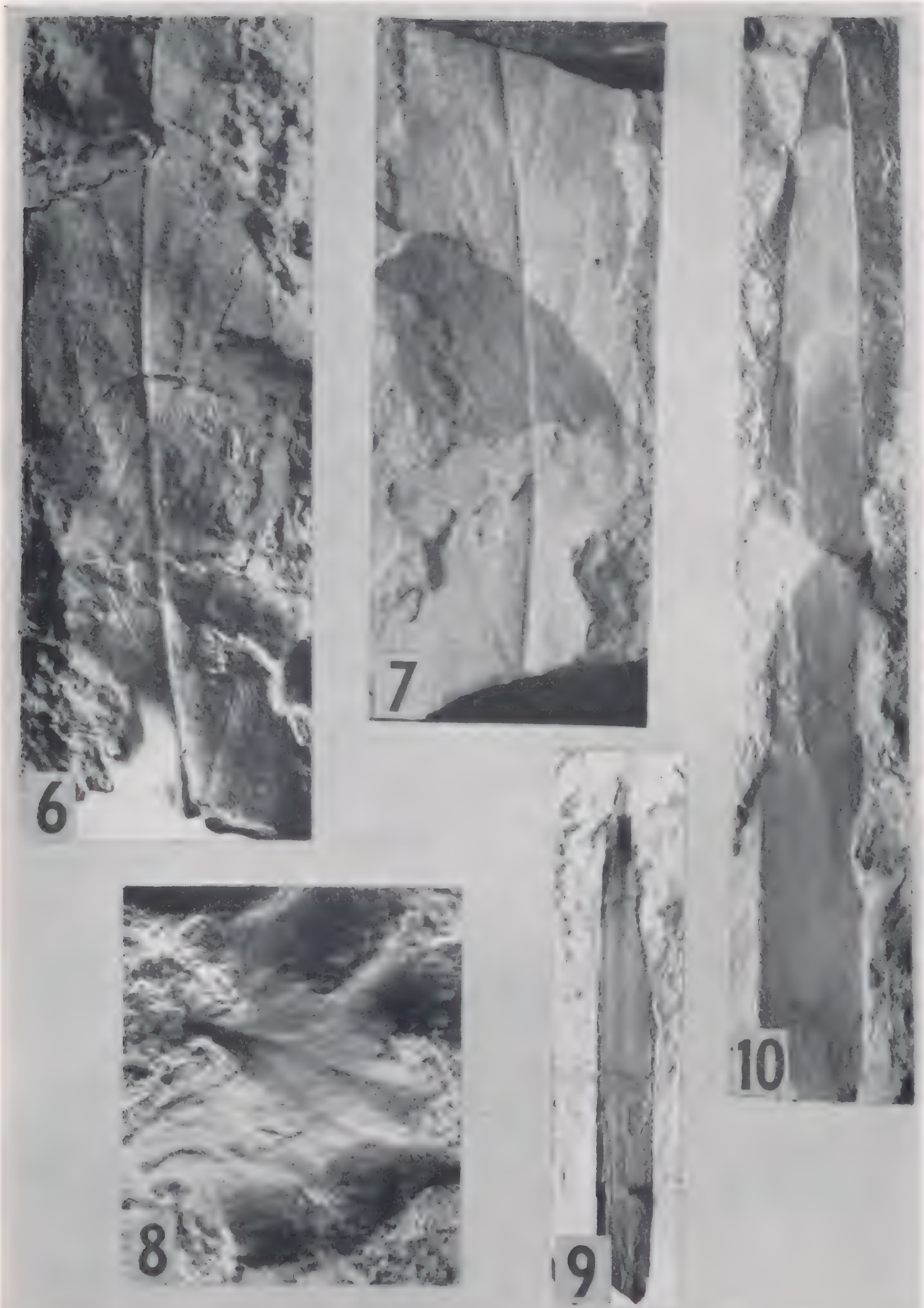
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THE GEOLOGY OF THE STRATHBOGIE IGNEOUS COMPLEX, VICTORIA

By D. A. White

[Read 9 April 1953]

Abstract

The members of the Strathbogie Igneous Complex are described and petrologically linked with other Upper Devonian igneous rocks in Victoria. In quartz-biotite-hypersthene dacite, garnet, hypersthene and cordierite have crystallized from a contaminated magma. Fluctuations in environmental factors have produced a second generation of cordierite and hypersthene which form poly-coronas and dactylites after pyrogenetic garnet. Anthophyllite pseudomorphs after hypersthene reflect the degree of assimilation in the basaltic magma. The dacite has metamorphosed a granodiorite porphyrite apparently related to the same period of igneous activity. The contact zone between the Violet Town Volcanics and the Strathbogie Granite represents an annular fracture along which large sedimentary blocks have subsided. This suggests the mechanism of emplacement of the Strathbogie Igneous Complex. Widespread aplites intruded along the fracture contact zone have metasomatized a granitic intrusion.

Introduction

The Strathbogie Igneous Complex consists of the Violet Town Volcanics and the Strathbogie Granite which, with the Terip Terip and Trawool Granites, forms a conspicuous mass in central Victoria. The complex occupies the western half of the County of Delatite and a small portion of the northern part of the County of Anglesey. The Hume Highway skirts its western edge and the Mansfield-Benalla road coincides with the eastern boundary. The Strathbogie Ranges with its highest peaks, Mt. Barrenhet, Mt. Separation and Mt. Wombat, form the high region (approximately 2,000 ft.) of the Strathbogie Granite province. Mr. Sugarloaf is a prominent landmark situated on the contact between the Violet Town Volcanics in the north and the Strathbogie Granite in the south.

Reconnaissance mapping was carried out by the author with the aid of aerial photographs, kindly supplied by the Mines Department of Victoria, detailed mapping being confined to the Violet Town Volcanics and its contact with the Strathbogie Granite.

Physiography

The Strathbogie Igneous Complex occupies the lowest elevated region of the north-western edge of the Eastern Highlands, and probably some of its summit levels represent relics of the Cretaceous Terrain prior to uplift and dissection. The mature undulating granite surface with a comparatively thick soil cover forms a contrast with the more dissected volcanic province. Differential erosion produces other contrasts in relief in the south, where the undulating granite country passes into the more dissected and symmetrical ridges of Silurian sediments. Physiography provides evidence for the emplacement of the Violet Town Volcanics as a scarp extends for about three miles at the foot of Mt. Sugarloaf parallel to the (fracture) contact zone between the volcanics and the Strathbogie Granite. The scarp was probably formed by movements associated with the emplacement

Fig. 1.—Geological Plan of the Strathbogie Igneous Complex.

of the volcanics. In this respect the large depression in the vicinity of Mt. Sugarloaf is also important.

The course of the main river, Seven Creeks, is influenced by the joint pattern in the Strathbogie Granite. The joints are vertical, widely spaced and trend N.N.E. and S.W., and in the late stage granitic intrusives they are closely spaced with a predominant N.N.E. trend. The joints in the volcanic province differ from those in the granite by their lack of orientation, closer spacing and in their association with horizontal joints. The variation in joint pattern and textural features in the two provinces is reflected in their present state of dissection.

The eastern boundary of the Terip Terip Granite is flanked by a prominent north-south scarp, which is produced by a fault parallel to the granite-sediment contact in the adjacent Silurian sediments.

The Barjarg Gap is an important physiographical feature separating the Tolmie Highlands in the east from the Strathbogie Ranges in the west and it provides a passage for the Broken River and the Benalla-Mansfield road. The Barjarg Gap has been linked with the formation of the disharmonious course of the Goulburn River, which was postulated by Fenner (1914) as the result of Tertiary block-faulting. Fenner's hypothesis was doubted by Hills (1932) who found evidence in support of differential erosion as the main structural control. The important points concerning the genesis of the Barjarg Gap are:

(i) The anomaly that exists between the gorge dissected in the granite ridge and the present Broken River.

(ii) The post-Strathbogie Granite fault which passes through the gap.

(iii) The resistant nature of the granite, which forms a small ridge in the gap (Summers, 1908).

(iv) The extensive alluvium deposits on the southern side of the gap extending towards the tributaries of the Goulburn River.

If the Strathbogie Ranges and the Tolmie Highlands were continuous in Upper Devonian times (Summers, 1908), the Barjarg Gap may have been the result of movements connected with the fault. However, from structural and petrological evidence it is doubtful whether the two provinces were continuous, and if this was the case the gap marks an important geological break (geocol) between two Upper Devonian Igneous Complexes. From its relationships with the Strathbogie Granite and a tinguaite dyke, the fault in the gap must be a late Palaeozoic or early Mesozoic event, and it is inconceivable that it had little or no effect on the formation of the Goulburn River system of which the Broken River is thought to have been a member.

The present gorge of the Broken River through the granite ridge, and the alluvium deposits, are evidence in support of Fenner's hypothesis (1914) that the original course of the Goulburn was through the Barjarg Gap.

Previous Work

Gregory (1903) postulated that the position of the pre-Older Basaltic divide was in the Strathbogie Ranges, an assumption which was later criticised by Hills (1934).

Summers (1908, 1914, 1923) established that a broad area of aplite separated a northern volcanic province, consisting of a "quartz-porphyrite" (now recognized as a quartz-biotite-hypersthene dacite) and an "adamellite-porphyry" (the

recrystallized dacite), from an "adamellite" (granite) in the south. Owing to the coarse nature of the quartz-porphyrite, Summers suggested that the northern Strathbogie rocks were entirely intrusive in character, and also he attributed the negligible metamorphism of the volcanics to the low temperature of the aplite intrusion.

Despite the fact that the Strathbogie Igneous Complex has been linked with other well-known Upper Devonian granodiorite-dacite provinces by previous Victorian authors, David (1950) considered it to be a late Middle Devonian intrusive.

Mr. G. Ampt's chemical analysis of the Violet Town "hypersthene quartz porphyrite" is quoted in Summers (1914). Edwards (1936) has analysed the garnet (almandine) of the dacite.

General Geology

Silurian Rocks

The Strathbogie Igneous Complex was emplaced through a bedrock of alternating fine-grained sandstones and mudstones, which are green when fresh and weather brown owing to the oxidation of iron to limonite. A few plant remains were found in a road cutting at the 103 mile peg on the Hume Highway between Euroa and Violet Town, but the age of the rocks is regarded as Silurian on the lithological similarity with other Victorian Silurian sediments. They have a general northerly strike.

Similar sediments are found as small inliers (screens) and pebbles between the volcanic and granitic provinces, where they serve as contact indicators where the contact is not apparent. The fine-grained sandstones in these inliers exhibit cross-bedding and contain water-worn pebbles up to ¾ inch in size, which weather out forming small depressions upon the surface. Owing to their rubbly nature the attitude of the sedimentary inliers could not be determined.

The Silurian bedrock is severely brecciated in places, and where the succeeding igneous material has broken through the bedrock, sediments are incorporated in a contact breccia.

The sediments have been contact metamorphosed to a black flinty hornfels. Tourmaline has been introduced by pneumatolysis forming segregations in the least metamorphosed sediments. Generally the volcanic side of the sedimentary inliers is marked by a dark hornfels band and the granite side is practically unmetamorphosed due to the low temperature of intrusion of the granite and to pre-existing structures in the bedrock which have influenced the intrusion of the Strathbogie Granite and late stage intrusives.

The Upper Devonian Rocks

These rocks constitute the Violet Town Volcanics, which are restricted to the north of the complex and represented as "Dacites" on the Geological Map of Victoria (1936). It is important to note that the "Dacite" area includes the hills east and north-east of Euroa and the hillock to the east of Five Miles Creek in the Warrenbayne Parish, both of which are shown as "Granitic Rocks" on the 1936 Geological Map. The Violet Town Volcanics consist of the following members:

(1) Rhyolite.
(2) Granodiorite porphyrite.
(3) Quartz-biotite-hypersthene dacite.

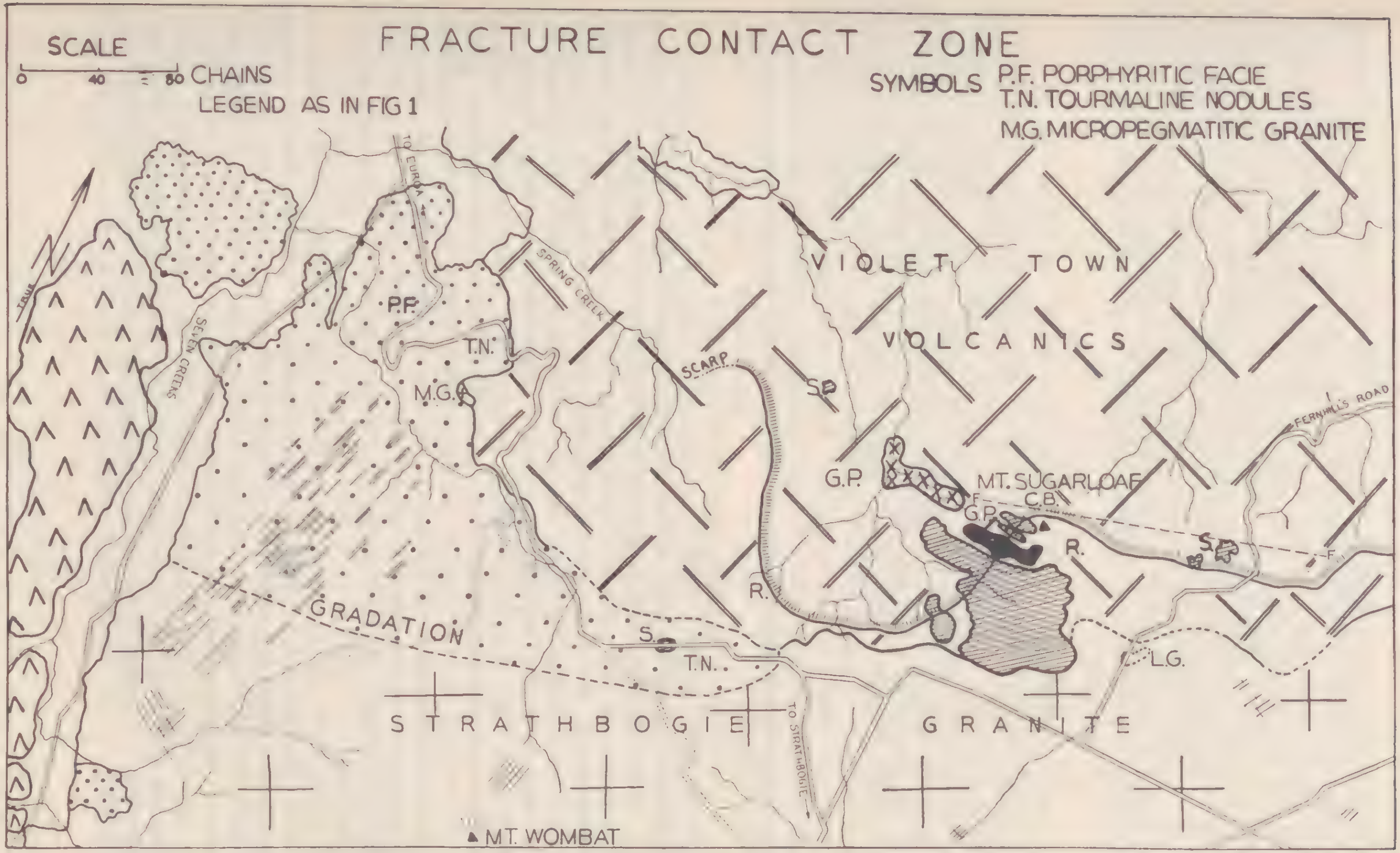

FIG. 2.—Detailed map of the western half of the fracture contact zone between the Violet Town Volcanics and the Strathbogie Granite.

Rhyolite

Volcanic activity began with the extrusion of a thin rhyolite flow on to an uneven bedrock surface. The basal rhyolite crops out with a low southerly dip in restricted areas along the northern edge of the volcanic province (Boho and Warrenbayne Parishes), where it is represented by xenoliths in the base of the dacite and in a contact breccia. Rhyolite xenoliths are rare along the western and eastern edges of the province, but they are conspicuous in the recrystallized dacite and the Mt. Sugarloaf contact breccia along the contact zone with the granite and sedimentary inliers. The rhyolite dips steeply to the north and is sheared on the western slopes of Mt. Sugarloaf. Although rhyolite is restricted in occurrence, the modified forms of rhyolite are the most important structural indicators of all the members in the complex.

Granodiorite Porphyrite

This rock is not strictly volcanic but is included with the Volcanics on petrological grounds. A small area of it occurs at the base of Mt. Sugarloaf, where it has been metamorphosed by the overlying dacite. Faulting has dislodged a small section of the outcrop into an elevated position on the western slopes of Mt. Sugarloaf. The granodiorite porphyrite is widespread as coarse acid schlieren in the younger dacite, which suggests that both were emplaced through a common channel or fracture in the bedrock. The porphyrite contrasts with the dacite in that it lacks bedrock xenoliths. Sufficient evidence is not available to determine the age relationship between the granodiorite porphyrite and the rhyolite. The porphyrite preceded the dacite, but mineralogical evidence suggests that they were closely related.

Quartz-biotite-hypersthene Dacite

The dacite is approximately 1,500 ft. thick and extends over most of the volcanic province. Mineralogically it is the important member of the Violet Town Volcanics, since it provides evidence for the petrogenesis of the complex. Many textural and mineralogical variations are encountered in this widespread flow. The hypersthene content decreases from the top of the dacite, seen at Fernhills Road, and grades to the north, east and west into a lower altered variety without any hypersthene, and into more recrystallized and possibly metasomatized varieties to the south towards the granitic province. The altered variety of the dacite grades into its chilled base, which contains abundant hypersthene, garnet and cordierite. The variable and gradational properties of the dacite evidently led Summers (1913) to divide the province into a "quartz porphyrite" and an "adamellite porphyry", but mineralogical and field evidence suggests that they belong to a single rock unit.

The dacite at its base contains many bedrock xenoliths and in the vicinity of Stony Creek it has brought the underlying rhyolite as xenoliths to the surface. It contains rare aplitic apophyses near the granite contact and exhibits evidence of metamorphism by increase in grain-size, biotite content and minor schistosity. Sedimentary xenoliths and acid schlieren increase in number towards the granite contact, especially on Mt. Sugarloaf, where they are accompanied by rhyolite xenoliths and terminate in hornfelsic and contact breccia types at several sedimentary inliers. The acid schlieren are numerous and elongated in the chilled base of the dacite.

The recrystallized characteristics are a feature of the dacite, and although recrystallization increases towards the granite, its widespread nature suggests that igneous activity other than the later granite was renewed after the formation of the dacite in the volcanic province.

The variable angle of dip of the contact of dacite with the sedimentary bedrock indicates that the dacite was both intrusive and extrusive. These characteristics together with the widespread occurrence of acid schlieren in the quartz-biotite-hypersthene dacite are very similar to those of the quartz-biotite-hypersthene dacite of the Black Spur area (Edwards, 1932). Similar schlieren are also characteristic of the quartz-biotite-hypersthene rhyodacite in the Cerberean Ranges (Thomas, 1947), and it is evident that the dacites are related to the same igneous activity.

The Epi-Devonian Rocks

These are intrusive, the main member being the Strathbogie Granite, which occupies the southern section of the complex. They comprise the main part of the petrographic province and are shown as "Granitic Rocks" on the Geological Map of Victoria, 1936. The eastern boundary of the Strathbogie Granite coincides with the 146° meridian and it extends west to Longwood, south towards Merton and south-west towards Seymour, where it grades into the Terip Terip Granite. In general it forms the highest part of the province (over 2,000 ft.) comprising the Strathbogie Ranges, Mt. Separation and Mt. Wombat. The intrusives can be classified as follows:

The Strathbogie Granite

The granite is the most widespread member of the Strathbogie Igneous Complex and exhibits three linear boundaries:

The eastern boundary coincides with a post-granite fault which passes through the Barjarg Gap. This fault is thought to be the northerly continuation of the Mansfield-Barkly fault (Thomas, 1947) and it has modified the trend of the Strathbogie Granite. The shattered granite is observed in a road cutting near the 18-mile road peg on the Benalla-Mansfield road, where two sets of shear planes are formed. The granite is intruded by a post-fault tinguaite dyke at this locality. Thomas (1947) has observed the Barjarg fault where carboniferous sediments are faulted against a band of fine-grained acid rocks, which are separated from the porphyritic cordierite Strathbogie granite by a narrow band of conglomerate. Contact metamorphism was not noticed along the eastern edge, over which there is a thick covering of Recent alluvium.

Along the southern boundary the metamorphic aureole is normally developed and different degrees of metamorphism exist. In general a narrow bend of high grade quartz-biotite-cordierite hornfels is in contact with the slightly chilled granite. This boundary was suggested by Fenner (1914) as the edge of a block fault and Thomas (1947) attributed the linear trend to pre-granitic faulting. Polished sections of the contact show the initial cross bedding of the sediments intact. The Silurian strike ridges are not disturbed in the vicinity of the granite and east-west faulting within a mile of the contact is absent. Moreover, lack of outcrops along this contact has probably assisted in its linear appearance on maps.

The eastern boundary of the Terip Terip Granite, which is continuous and identical with the Strathbogie Granite, is linear and the wall rocks consist of the usual narrow band of cordierite hornfels. A fault with a considerable throw strikes parallel to the contact in the Silurian sediments to the west of Godfrey's

Creek, and is represented by a scarp extending for three or four miles in a northerly direction. The youthful state of dissection of the scarp suggests a Tertiary age for the fault but the emplacement of the granite may have been influenced by northerly trending lines of weakness in the sedimentary bedrock.

The Strathbogie Granite grades into finer grained leuco-granites along the contact with the Violet Town Volcanics and possesses gradational or semi-intrusive relationships with late stage granitic intrusives. The leucocrates are generally separated from the dacite by sedimentary inliers or aplites and, in agreement with their gradational relationships with the granite, may be interpreted as a chilled border facies of the Strathbogie Granite. This is supported by the greater abundance of cordierite phenocrysts in the leucocrates similar to those in the main granite. Against this, however, sheared orthoclase phenocrysts in the granite over the gradational zone suggest a separate intrusion for the leucocrates, particularly the aplites. It is apparent from field and microscopical evidence that little time lapsed between the formation of the leucocrates and the intrusion of the aplites between the volcanic and granitic provinces.

Micro-pegmatic Granite

This occupies a restricted area along the contact between the wide aplite belt and the dacite, where metasomatism by later aplitic intrusives has produced a marked porphyritic texture in this granite. The granite grades into the Violet Town Dacite in the field, but from mineralogical evidence it has apparently been derived from the Strathbogie Granite and is tentatively listed here under the Epi-Devonian intrusives.

Late Stage Intrusives

These consist of biotite, tourmaline, cordierite and micro-pegmatitic aplites. They are concentrated along the granite-dacite contact and are exposed along the more eroded western part, where they form a large wedge-shaped zone, tapering along the contact towards Mt. Sugarloaf and Mt. Separation in the east and widening towards Euroa in the west. In general the belt occupies a wide depression separating the dacite and sedimentary inliers to the north at Mt. Sugarloaf and the granitic highlands at Mt. Wombat to the south.

Small biotite aplites also intrude the Strathbogie Granite as dykes, which are variable in strike when compared with the wider tourmaline-bearing aplites, in which quartz-tourmaline nodules are frequently formed. The tourmaline-bearing aplites conform to an east-west strike (i.e. parallel to the granite-dacite contact zone) and intrude the dacite; however, the aplites grade into the leuco-granites, which in turn possess gradational relationships with the granite.

The Barjarg Granite

This occupies the high ground at the junction of the Broken River and Sandy Creek in the Barjarg Gap. The granite is considered to be closely related to the Strathbogie Granite and it has been sheared by the fault which passes through the Barjarg Gap.

Metamorphic Rocks

Low grade hornfels occurs between the Violet Town Volcanics and the relatively unaltered sedimentary bedrock. The high grade flinty quartz-biotite-cordierite hornfels is exposed over a zone of variable width up to 15 feet along the southern

Strathbogie Granite and sedimentary contact. Members of the volcanic formation are in contact with the sedimentary inliers on Mt. Sugarloaf, where quartz-biotite hornfels is formed together with peculiar hybrid types and contact breccias, whose composition and texture depend upon the degree of admixture of sediment and volcanics as well as the amount of flow of the lavas. The contact breccia is also formed on the western ridge of Stony Creek, where the dacite has broken through the sedimentary bedrock and basal rhyolite, both of which form the main part of the breccia.

Cainozoic Rocks

Limburgite

This occurs as a flow situated about three miles south of Euroa, occupying a narrow strip approximately six miles long on the western banks of Seven Creeks. Hills (1938) correlated it with the younger members of the Newer Volcanic Series on physiographic evidence. The flow is approximately 30 feet thick and exhibits columnar jointing. Scoria, ash beds and volcanic cones associated with the limburgite have been mentioned by Dunn (1914).

Tinguaite (?)

This occurs as a dyke, exposed in an extremely weathered condition in a road cutting on the Mansfield-Benalla road near the 18 mile road peg. It intrudes the intensely sheared Strathbogie Granite along one of the shear planes. The dyke is post-granite and post-Barjarg faulting and it probably belongs to the dyke swarm of the Older Volcanics, which are so common in eastern Gippsland. Similar dykes have been recorded by Skeats in the Tolmie Ranges and he has correlated these and those of Tabberabbera and Omeo (1928) with Middle to Late Cainozoic alkali rocks of the Mt. Macedon and the Western Districts. Moreover, Skeats believes that they have been intruded along tension cracks associated with differential movements of the eastern Australian uplift, and from this aspect the association of the Barjarg tinguaite dyke with faulting is important.

Petrology

General Characteristics of the Petrographic Province

The consanguinuity of this comagmatic province is revealed in the mineralogical, textural and geological associations of each member of the suite. The characteristic feature of the volcanics is the presence throughout of coarse acid schlieren of granodiorite porphyrite, which are more elongated in the base than the upper parts of the quartz-biotite-hypersthene dacite. Xenoliths of sedimentary rock and rhyolite occur in the dacite, particularly at its base.

The acid affinities of the province are revealed by the predominance of quartz amongst the phenocrysts. Hypersthene, cordierite and garnet are always present in varying amounts, either alone in their corroded and altered forms or as a reaction trio in the garnet-cordierite-hypersthene coronas and the associated dactylites. The amount of hypersthene fluctuates between the upper and basal portions of the dacite and is at a minimum in the altered, metasomatized(?) and recrystallized varieties.

Approximately ninety per cent of the Strathbogie Complex consists of granite and dacite and most of the members are coarse-textured and porphyrite. Owing to these features the members of the volcanic province are difficult to visualize as belonging to the extrusive class of igneous rocks. The plagioclases are andesine

and in excess of the potash felspars in the earlier rock types; however albite-oligoclase with potash felspar, sometimes microperthitic, are prominent in later differentiates. The potash content increases from the oldest to the youngest member in agreement with the variation in the felspar composition and potash is in excess in the granite and late stage intrusives. Tourmaline is prominent amongst the groundmass constituents and it is present in greater amounts in the aplites, where it is mainly represented by quartz-tourmaline nodules.

There is a tendency for igneous contacts to be gradational throughout the province. This is exemplified by the change from the chilled dacite base through an altered dacite form to the widespread recrystallized dacite, which in turn grades into a porphyritic metasomatized granite. The gradation across the strike in the intrusives is from fine-grained biotite aplites through porphyritic leuco-granite facies to the coarse porphyritic Strathbogie Granite. The granite-dacite contact is poorly defined but often along this contact sedimentary inliers forming an abrupt hornfels contact with the dacite grade, on the granite side, into the late stage granitic intrusions which flank the granite along this contact zone. Gradational characteristics are also present in the individual members of the complex.

Although metamorphism and metasomatism have produced important mineralogical changes in some members of the complex, their effects are limited and the schistose and gneissose structures present in other Victorian dacites are rarely observed in the dacite, owing to the influence of pre-existing structures upon the granite emplacement. The degree of metamorphism between the Strathbogie Granite and the sediments varies in the south probably owing to the variable composition of the wall rocks or removal of the products of reaction by convection.

Petrography

Rhyolite

Rhyolite either is recognized as a flow or as recrystallized and cataclastic xenoliths in the dacite. It is highly porphyritic, quartz up to 4 mm., terminated by rhombohedra, being the most conspicuous feature. Veinlets of secondary quartz and tourmaline have been introduced into the groundmass, in which viriditic particles conform to a definite flow pattern. The accessory minerals comprise serpentine and other chloritic material after cordierite, garnet with poikiloblastic inclusions of magnetite and biotite, as well as biotite segregations after sedimentary inclusions. The texture of the rhyolite resembles a nevadite, but it differs from other Victorian Upper Devonian Nevadites by the absence of subordinate acid plagioclase phenocrysts.

In the recrystallized rhyolite xenoliths the groundmass changes from cryptocrystalline to microgranular, orthoclase tends to be microperthitic, and with the development of lacinear borders orthoclase and quartz increase in size, quartz embayments are destroyed and both quartz and orthoclase become anhedral. Original garnet possesses a sieve texture in the new environment and owing to reciprocal reaction between xenolith and host biotite increases in content. In general, with increase in recrystallization of the original rhyolite nevadite affinities are more apparent.

In thin section the cataclastic recrystallized rhyolite possesses a blastoporphyritic texture, in which quartz, in particular, and orthoclase phenocrysts are intensely sheared. Quartz and to a lesser extent orthoclase have been considerably elongated by the overriding of brecciated segments. Preferred shearing planes are recognized in the phenocrysts and despite its xenoblastic appearance the original

embayed form of quartz is preserved. Biotite is flexible to the shearing force and tends to segregate into glomeroporphyritic clusters. However, if the prominent (001) cleavage of biotite coincides with the shear, shearing and gliding of cleavage segments occur along the cleavage planes. Cordierite is never preserved in the fresh state, and is altered to an aggregate of pinite and a bronze-coloured mineral with no cleavage, high refractive index and practically isotropic. Sedimentary xenoliths derived from the adjacent inliers are numerous.

It is apparent that there are several varieties of the basal rhyolite flow ranging from the original unaltered flow through various recrystallized and micro-mylonitic types, which depend on their structural setting in the Violet Town Volcanics. The recognition of all varieties of rhyolite is very important in the final interpretation of the structure of the volcanics.

Granodiorite Porphyrite

The granodiorite may enter the Tonalite class with chemical analysis, but it is tentatively listed as a granodiorite. As with rhyolite, different varieties of the granodiorite can be recognized according to its structural setting in the Violet Town Volcanics.

Micro-granophyric Granodiorite Porphyrite. Doubly-terminated quartz crystals up to 7 mm., oscillatory zoned plagioclase (Ab_{62}), biotite and pinitized cordierite phenocrysts are set in a micro-granophyric groundmass. The plagioclase phenocrysts tend to form haphazardly on to each other, emphasizing their size up to 4 mm. Biotite is usually chloritized. Preferred pinitization directions in cordierite parallel cleavage and twin planes and the usual green pinite product is accompanied by a yellow to colourless isotropic alteration. Accessories are zircon, enclosed in biotite, apatite, magnetite and muscovite. The groundmass is the characteristic and distinguishing property of this rock. All varieties of quartz and orthoclase intergrowths are present, ranging from micro-pegmatite through micro-spherulitic to cryptographic associations. Subordinate micro-phenocrysts of plagioclase are also present in the groundmass.

Dark clots associated with biotite are also another feature of the granodiorite porphyrite. The centres of these segregations consist either of anthophyllite pseudomorphs after hypersthene, or cummingtonite and quartz. The anthophyllite pseudomorphs contain apatite and the magnetite inclusions of the original hypersthene. The anthophyllite fibres are generally replaced by biotite. Occasionally antigorite pseudomorphs the pyroxene. The cummingtonite is in small plates or sheaves of needles associated with quartz, biotite, magnetite and pyrrhotite. These minerals are surrounded by an inner brown biotite rim, which grades out into an outer dark green biotite in contact with the groundmass. The change in colour of biotite may be the initial stages in the deuteric alteration to chlorite. The mineralogy of the granodiorite porphyrite suggests that it is closely related to the quartz-biotite-hypersthene dacite.

Cataclastic and Recrystallized Granodiorite Porphyrite. This variety is represented by the acid schlieren in the dacite. The twin lamellae of plagioclase phenocrysts are slightly flexed. Segmentation of quartz and plagioclase has taken place owing to the increase in granularity of the groundmass. Sericitization of plagioclase is most marked in the rounded granodiorite porphyrite xenoliths of the dacite along the eastern part of the dacite-granite contact. The original granophyric texture of the groundmass is partially destroyed in the chilled base of the dacite

and it is granular in the extreme recrystallized dacite types. With the change in granularity of the groundmass the original subhedral and embayed form of quartz is destroyed and lacinear borders are prominent around plagioclase. Biotite shows little change, except for slight flexing and an apparent decrease in the width of pleochroic haloes surrounding enclosed zircons. Hypersthene or its pseudomorphs are generally altered to a dark green biotite with precipitation of iron ore.

Schistose Granodiorite Porphyrite. The quartz-biotite-hypersthene dacite has metamorphosed the granodiorite porphyrite into fine and coarsely schistose porphyrite. Interlocking dark biotite flakes segregate and form discontinuous parallel bands between mosaics of quartz porphyroblasts. The microphenocrysts of plagioclase form segregations in the groundmas and quartz is recrystallized into mosaics, which are elongated parallel to the schistosity. Segmentation of the original phenocrysts by the groundmass is an additional feature of the coarse schistose porphyrite.

The schistose granodiorite porphyrite differs from the schistose hypersthene dacite at Warburton and Selby by the absence of hornblende. This suggests that temperature and pressure conditions were low at the time of the emplacement of the dacite at Violet Town.

Quartz-biotite-hypersthene Dacite

The most notable feature of this widespread flow is the abundance of gleaming black biotite flakes and coarse acid schlieren of granodiorite porphyrite (Plate V, fig. 1). The dacite has a very coarse texture when compared with that of normal lavas, weathers easily and is contaminated with small bedrock hornfels xenoliths. Acid schlieren in the chilled base are small and elongated. As is to be expected in such widespread flow, considerable variations are observed. Towards its base it is extremely altered and light green in colour. Hypersthene is rare in the altered variety and its content decreases in the recrystallized types towards the granite contact. The altered section of the dacite grades into its dark chilled base, where hypersthene, garnet and cordierite are in abundance.

Anhedral slightly embayed quartz, zoned plagioclase (Ab_{54}-Ab_{60}), altered hypersthene, biotite, together with occasional corroded garnet and pinitized cordierite, are set in a highly potassic microgranular groundmass. Orthoclase is absent as phenocrysts but is abundant in the groundmass, especially in the recrystallized varieties of dacite.

Pleochroic hypersthene (X = pinkish red, Y = light yellow, Z = green) is rarely observed by itself; it either paramorphically alters to a plum-brown, slightly pleochroic anthophyllite or to biotite. All stages from the incipient alterations to the complete anthophyllite or biotite pseudomorphs can be observed. Metasomatic hypersthene also occurs as small enhedral grains in an outer rim surrounding an inner cordierite corona about garnet. Garnet and cordierite are the important accessories, and together with hypersthene form an interesting reaction trio, which will be discussed later. Cordierite is pinitized and rarely pseudomorphed by beam textured serpentine; sillimanite needles, dark green spinel octahedra, and dusty iron ore surrounded by pleochroic lemon-coloured haloes are seen in the cordierite core.

The grainsize of the groundmass ranges from fine microgranular, in which acid schlieren can be recognized (i.e. in the base of the flow) through all microgranular stages to a final coarsely recrystallized groundmass, which tends towards

micro-granitic affinities. With increase in grainsize, the high potassic nature of the groundmass becomes more apparent, and lacinear borders are produced around quartz and plagioclase phenocrysts, as they appear to grow in size and enclose grains of the original microgranular groundmass around their borders; thus the original plagioclase develops a narrow rim of orthoclase. Owing to this increase in grainsize, quartz embayments lose their definition. Blue tourmaline, together with minor amounts of magnetite, zircon and apatite are present in the groundmass. Pennine occurs after anthophyllite or biotite in the more recrystallized dacites.

The altered portion of the dacite towards the base is characterized by sericitized plagioclase, quartz, chloritized biotite, corroded garnet, pinitized cordierite and extremely rare and corroded hypersthene. In the extreme cases of chloritization, sphene and epidote are relegated to the cleavage traces of biotite. Chloritization increases, biotite content decreases, hypersthene is practically absent, and sericitization is intensified and especially marked around included bedrock fragments in the lowest sections of the dacite. Also with increase in assimilation of rhyolite at the base the quartz-biotite-hypersthene dacite exhibits toscanite affinities. The chilled base of the dacite contains phenocrysts of quartz, plagioclase (Ab_7-Ab_6), biotite, altered hypersthene, conchoidal fractured garnet up to 1 mm. and occasionally pinitized cordierite up to 2 mm. set in a microcrystalline to hypohyaline groundmass, in which various viridites and opacites conform to the flow lines. Quartz and plagioclase are also present as small angular fragments in the groundmass. A characteristic feature of the groundmass is the sudden change from the usual microcrystalline to a radiolitic texture, producing a patchy effect over wide areas, the patches being usually drawn out in schlieren-like fashion. Their association with xenoblastic segmented plagioclase with flexed twin lamellae, similar to those in the granodiorite porphyrite schlieren, and their occasional micrographic texture, clearly point to their derivation.

The Strathbogie Granite

The Strathbogie Granite and Terip Terip Granite are parts of the same mass and the two rocks are identical. Baker (1940) described the Terip Terip Granite as a "potash rich, two mica cordierite granite" and in places it tends towards adamellite affinities. The Strathbogie Granite is coarse, porphyritic and easily weathered. The following additional features have been observed in the Strathbogie Granite as well as those recognized by Baker in Terip Terip Granite:

(i) The tendency for zoned oligoclase to become antiperthitic and possess a rim of orthoclase or albite. The potash intergrowths are present in small numbers and exhibit euhedral outlines.

(ii) The existence of a brownish-grey isotropic mineral, with refractive index less than that of cordierite, in association with the usual green micaceous products ("pinte") and rare serpentine after cordierite. It appears to be the initial alteration product of cordierite, which finally alters to the usual pinite aggregate.

(iii) The occasional micrographic nature of the microperthite. Myrmekitic bordered microperthite occurs along the Molesworth contact edge.

(iv) Rare biotite-orthoclase dactylitic intergrowths.

(v) Pink-red garnets up to 1½ cm. altered to green micaceous products and biotite.

The Strathbogie Granite becomes slightly less coarse-grained towards the contacts, especially along the contact with the dacite. Sedimentary xenoliths up to 10 inches are rare and represented by aggregates of biotite flakes.

The leuco-granites along the contact between the Strathbogie Granite and the dacite are fine-grained and porphyritic, and differ from the Strathbogie Granite in texture and biotite content. The leucocrates resemble granite porphyries and range from granite porphyry to granodiorite porphyrite. Crystals of cordierite with pinite are common. The felspar phenocrysts are similar to those in the main granite and the potash groundmass exhibits graphic tendencies.

Micro-pegmatitic Granite

As a result of metasomatism by the late stage instrusives, orthoclase, up to 3 cm., and quartz porphyroblasts, occasionally associated with muscovite, are set in a medium-grained groundmass of felspar and biotite. Veinlets of orthoclase containing an inner quartz vein traverse the metasomatized granite.

The obvious porphyritic nature of the hand specimen is not apparent in thin section. Orthoclase is in excess of albite-oligoclase, which is sericitized and surrounded by a rim of orthoclase. Orthoclase and quartz form micro-pegmatitic and micro-granophyric intergrowths. Myrmekitic plagioclase is rare. Pinitized cordierite, ranging from phenocrysts of 4 mm. to groundmass size, with sillimanite and quartz inclusions are abundant. Muscovite, biotite, secondary quartz and rare garnet comprise the remainder of the even grained granitic groundmass.

The nature and abundance of biotite, together with field evidence, suggests that this rock may have been derived from the quartz-biotite-hypersthene dacite; however, the plagioclase composition, and size and alteration of the cordierite, leave little doubt that the micro-pegmatitic granite must be related to the Strathbogie Granite.

Late Stage Instrusives

The biotite aplites which intrude the Strathbogie Granite are narrow, fine-grained, and contain no tourmaline nodules. The widespread aplites concentrated along the granite-dacite contact zone are coarse, wide, and frequently contain tourmaline nodules and cordierite. Microscopically, microperthite, albite-oligoclase, quartz and muscovite form a saccharoidal texture, in which potash felspar is slightly in excess of soda felspar. The aplites along the contact zone are intruded by small tourmaline-bearing pegmatitic veins, around which the potash felspar possesses micropegmatitic borders. Tourmaline is either interstitial to quartz, black needles filling small vughs or in nodules associated with quartz and felspar.

The quartz-tourmaline nodules are conspicuous against the white aplitic background and, owing to their resistance to weathering agents, they project above the host in a wart-like fashion. The nodules are elliptical and in the fine-grained biotite aplites they tend to possess a cream felspar halo. They vary from ½ inch to 3 inches in diameter and their border with the host is irregular and abrupt. Quartz and altered felspar are present throughout the nodule, quartz being in excess owing to the replacement of the orthoclase by tourmaline. The tourmaline is the schorlite variety. It favours replacement of cloudy microperthite with the liberation of quartz. Albite-oligoclase is more resistant to tourmalinization and is generally altered to an aggregate of kaolin, chlorite, muscovite (rare), quartz and analcite. Tourmaline in the outer regions of the nodules is interstitial to quartz and felspar, with anhedral topaz often associated with it. Similar nodules have been described by Edwards (1936) from the granite of Clear Creek, near Everton.

The main biotite-tourmaline-cordierite aplite separating the Violet Town Volcanics from the Strathbogie Granite grades towards its centre into a leuco-

adamellite porphyry, whose porphyritic texture is more marked and distinct from that of the leuco-granite border facies. The adamellite porphyry contains phenocrysts of euhedral perthite, an inch in size, and subhedral albite-oligoclase of about half an inch, together with microphenocrysts of quartz, cordierite and biotite, set in an even medium saccharoidal textured groundmass of the same minerals. The felspar phenocrysts exhibit sericitized and myrmekitic characteristics and a high soda content of the perthite phenocrysts is indicated by the optical properties determined on their fragments.

The Barjarg Granite

The normal rock possesses a dark orange colour owing to the predominance of felspar. Where intensely sheared the granite is green because of the strong development of biotite. Orange-coloured felspar and quartz form the main part of the coarse-textured granite with interstitial dark green biotite, muscovite and dark cordierite pseudomorphs comprising the remaining accessories.

Microscopically, the felspars are albite-oligoclase and microperthite, with numerous inclusions of dusty iron ore, which contributes to their colour. The twin lamellae are flexed and anhedral quartz exhibits undulatory extinction in the sheared granite. Quartz and felspar contain stringers of orthoclase. The microperthite intergrowths tend to become microcline-microperthite as very fine lamellar twinning is observed in the potash section of the intergrowth. In this respect it is interesting to note that Chayes (1952) has recently noticed the marked tendency for perthitic microcline to be associated with highly undulant or granulated quartz. Albitization is also a feature of the Barjarg Granite, which is probably an end member of the Strathbogie Granite. The pseudomorphs after cordierite are serpentine and muscovite. Summers (1908) described this granite without any mention of the sheared specimens and the occurrence of cordierite.

Metamorphic Rocks

The formation of quartz-muscovite hornfels is the first sight of contact metamorphism in Silurian impure sandstones or mudstones. With increase in grade, reddish-brown biotite is formed and later accompanied by cordierite which is developed in place of andalusite owing to the relatively high iron and magnesium content of the original sediment. Cordierite is turbid in the high grade hornfels, as well as altered in small amount to pinite, and contains pools of quartz. A narrow spotted zone of grey-green cordierite can be observed in polished specimens of the granite-hornfels contact in the south. Also in the same specimen the original cross-bedding of the sediments is preserved and ptygmatic-like folds are formed to within an inch of the granite contact edge (Plate V, fig. 3).

The hybrid hornfelsen on Mt. Sugarloaf resemble quartz-porphyries, but under the microscope they are confirmed to be hornfels made up of quartz segregations, numerous small biotite flakes either in clots or diffused in the groundmass, sheared orthoclase and plagioclase crystalloblasts. Orthoclase, plagioclase or biotite are in excess, depending upon the degree of admixture of rhyolite, dacite and sediment respectively.

The contact breccia consists of rounded rhyolite xenoliths up to 4 cm. and numerous angular bedrock hornfelsic xenoliths set in a confused rhyodacitic matrix (Plate V, fig. 2). In addition the contact breccia at Mt. Sugarloaf contains abundant granodiorite porphyrite schlieren. The original bedding of the sediments can still be recognized, and biotite either alone or with garnet is developed in the

rhyolite xenoliths owing to assimilation by the dacite. The felspars of the breccia are either orthoclase derived from the rhyolite or kaolinized and sericitized plagioclase from the dacite host. Clear anhedral quartz is conspicuous in the strew of the breccia, being mainly derived from quartz phenocrysts of the rhyolite.

Limburgite

Edwards (1938) classified this flow and gave its chemical analysis. Hills (1938) discussed its age and petrography.

Tinguaite(?) *Dyke*

The dyke is a foot wide and is extremely weathered, ranging from a grey-blue colour, through brown to a white clayey substance. In all stages small white felspar laths can be seen.

In thin section, what was probably nepheline in euhedral crystals up to 2 mm., and laths of felspar, now completely altered, lie in a tinguaitic groundmass of numerous iron ore needles and nepheline(?). The alteration products after nepheline are of weak birefringence and probably zeolites, occasionally accompanied by a pale-coloured mineral exhibiting good cleavage and first order yellow interference colours, presumably cancrinite. The iron ore is probably the result of extreme alteration of the original pyroxene, probably aegirine.

Mineralogy

Hypersthene and Its Alterations (Plate IV, figs. 1 and 2)

The hypersthene content fluctuates in the quartz-biotite-hypersthene dacite but it is the characteristic constituent. Hypersthene occurs as a primary mineral of crystallization and also as a constituent of coronas about garnet. The pleochroism of the primary hypersthene (X = pinkish red, Y = light green, Z = green) varies in intensity, but it is usually in agreement with a relatively high iron content. This hypersthene reacts with orthoclase to form biotite, as in other Upper Devonian Dacites of Victoria and in a related porphyrite at Tooborac (Singleton, 1949). Summers (1923) recognized biotite and "rather rare examples of corroded hypersthene" in the Strathbogie Ranges, from which he suggested "that the temperature at which crystallization ceased had been sufficiently low for the reaction between the hypersthene and felspar to be almost complete." Edwards (1932) explained the hypersthene-biotite reaction from evidence obtained in the Black Spur Dacites. The hypersthene alteration trends in the Violet Town Dacite support the influence of his postulated "environment" factor in this reaction. Owing to rapid cooling and low potash content, hypersthene in the base of the dacite exhibits only a narrow rim of biotite (red brown or dark green); however, with slower cooling and increase in orthoclase content, deep biotite coronas are produced around hypersthene in the upper sections of the dacite.

Hypersthene also shows a marked tendency for a paramorphic alteration to anthophyllite in the quartz-biotite-hypersthene dacite. Edwards (1932) described a similar alteration in an anthophyllite-garnet rock in the Warburton granodiorite-dacite contact zone. The recognition of anthophyllite is based on purely optical data and although Rabbitt (1948) has shown by X-ray study that pseudo-orthorhombic properties can be obtained from amphibole asbestos specimens with an apparent parallel extinction, the more prismatic amphibole sections possess definite parallel extinction and they are assumed to conform with the properties

of anthophyllite. Generally anthophyllite occurs outside the original brown biotite rim of the hypersthene and in turn it alters to a brown-green biotite, which grades into a green variety on the outer edges. Tattam (1924) noticed the adjustment in composition of the original red-brown biotite in accidental xenoliths of the Bulla Granodiorite. On chemical analyses (1929) he considered the somewhat greenish colouration in brown biotite occurring in certain quartz-mica-diorites and granites to be due to the high lime content. In this respect the alteration of anthophyllite to a green biotite is of some importance, as appreciable amounts of calcium are common in the aluminous anthophyllite molecule. However, Hall (1941) showed that the colour is very little indication of the composition of biotite. Anthophyllite is altered hydrothermally to antigorite (bastite) towards the granite contact. Edwards considered the alteration of hyersthene to anthophyllite due to special conditions of metamorphism at Warburton, in which pressure was an important factor. The Violet Town Dacite reveals signs of metamorphism by its recrystallized groundmass, but the anthophyllite pseudomorphs appear to be independent of metamorphism. Moreover, the occurrence of anthophyllite outside as well as in place of the original biotite rim about hypersthene suggests that it has formed by reaction of hypersthene with the groundmass constituents prior to consolidation. Although the normal alteration trend for hypersthene is to a green hornblende, alteration to anthophyllite was preferred in the Violet Town Dacite and its formation was caused by one or more of the following:

(i) Stresses operating during the final stages of crystallization.
(ii) Change from dry to wet conditions.
(iii) A deficiency in calcium and an excess of alumina in the magma.

The co-existence of pyrogenetic garnet and cordierite (anti-stress minerals) in the dacite raises doubt as to the value of pressure control in the formation of anthophyllite (stress mineral). Moreover, from the decomposition products of garnet and cordierite, described later, it is deduced that reduced pressure and excess alumina and silica were the predominant factors in the final stages of crystallization of the residual magma. Evidently hypersthene can be stable under wet conditions (Wilson, 1952), so that the alteration of hypersthene to anthophyllite does not necessarily imply a change from dry to wet conditions. Although hydration must have been important in the change from hypersthene to amphibole, evidence supports the deficiency of calcium and excess alumina as the critical factor in the formation of the anthophyllite. Rabbitt (1948) has shown that the anthophyllite series is a three-component one of limited isomorphism involving chiefly Mg, Fe and Al. That calcium was deficient in the magma is revealed with comparison of the chemical analyses of the Violet Town Dacite (Summers, 1914) and the similar dacite at Black Spur (Edwards, 1932), where hypersthene readily decomposes to biotite. The fluctuations in the calcium, sodium and potassium contents between the Violet Town and Black Spur Dacites can be explained partly by the differences in composition of zoned plagioclases between the two similar dacites and partly by the calcium deficiency in the transformation of the hypersthene to anthophyllite instead of hornblende.

When the breakdown of hypersthene in the Violet Town Dacite is considered in the light of Edward's "environment" hypothesis, it is obvious that, although cooling conditions and abundance of potash were favourable for the complete replacement of hypersthene by biotite, chemical factors were not completely favourable for the formation of extensive biotite or hornblende. Hence it appears that

hypersthene crystallizing slowly under conditions of low calcium, excess aluminium and hydroxyl ions, is rendered unstable and replaced by anthophyllite, in which more Fe Mg and Si atoms can be replaced by Al atoms.

Garnet Coronas and Associate Dactylites

Although not as abundant as cordierite or hypersthene, garnet is an important constituent of the quartz-biotite-hypersthene dacite, and to a lesser extent of the basal rhyolite and granitic rocks. Its presence is a common feature in the Victorian dacites and associated rhyolites of similar age. Almandine is the predominant molecule of the garnet (Edwards, 1936). Garnet occurs as small unaltered fragments in the chilled base of the dacite but elsewhere it is unstable and surrounded by an inner cordierite corona, containing small vermicular intergrowths, and an outer hypersthene rim. The garnets in the Strathbogie Granite are associated with assimilated sedimentary xenoliths and possess an irregular border; they are rimmed with sericitized and pinitized cordierite and, unlike the garnets in the dacite, the cordierite contains numerous inclusions of biotite, apatite and iron ore.

The cordierite rim in the dacite consists of numerous anhedral interlocking crystals (2V approx. 80°), is larger than the hypersthene rim, and increases in size as garnet is resorbed. Unlike the presumed primary cordierite of the dacite, it is practically unaltered, probably owing to its protective hypersthene rim or the dry conditions of formation. Hypersthene granules comprise the incipient outer rim, which in comparison with the cordierite rim exhibits little change in width. Cordierite forms a continuous rim about garnet, whereas hypersthene is discontinuous and generally the hypersthene anhedra are absent or decrease in number where felspar or biotite are in contact with the cordierite rim. As resorption of garnet is completed, hypersthene loses its identity by dispersion in the groundmass or alteration to biotite. In general the inner cordierite rim increases inwards at the expense of the garnet and hypersthene towards the groundmass.

Dactylites in the cordierite project radially from the garnet to within a short distance of the outer hypersthene rim and owing to their minute thickness they are colourless. Their composition is difficult to assess; the rarer, thicker and more rounded types usually included in the slender and transparent dactylites are hypersthene, and on the assumption that there has been no loss of material in the whole garnet structure, the clear dactylites which show variation in extinction angle must also be a ferromagnesian silicate. Moreover, from consideration of the garnet analysis (Edwards, 1936) it can be assumed that the hypersthene both in the outer rim and dactylites contains a considerable proportion of the iron originally present in the garnet. The dactylites and the outer hypersthene rim are closely related as only on rare occasions is hypersthene present without the dactylites.

Towards the base of the dacite the garnet coronas and associated dactylites are rare and altered. Cordierite is altered to a sericite aggregate, the dactylites to a green biotite, and the outer hypersthene is either absent or replaced by biotite. The alteration of the dactylites to biotite also suggests that the dactylites were originally a pyroxene.

Besides the above occurrence, altered cordierite and brown biotite surround garnet. This cordierite resembles the presumed pyrogenetic cordierite in the rest of the dacite and garnet appears stable, since it does not possess the usual sieve border structure of unstable garnets. This may represent the formation of garnet

accompanied by a little muscovite by the action of cordierite and biotite, for which Tattam (1925) provides a probable equation.

Another important and restricted occurrence of garnet is when it is surrounded on one side by a felspar corona and on the other by cordierite with associated dactylites and outer hypersthene rim, i.e. the one garnet exhibits stable and unstable characteristics (Plate IV, fig. 4). Garnet and felspar are idiomorphic along the contact with each other and the felspar is either a single twinned crystal or several euhedra of the same composition as plagioclase phenocrysts in the remainder of the dacite. Edwards (1936) regarded rims of idiomorphic felspar containing zircon and epidote(?) grains identical with those enclosed in embayed garnet as representing "reject matter" in the growth of garnet, and in other cases contemporaneous crystallization of felspar and garnet was evident. In the Violet Town Dacite, felspar does not appear to be "reject matter" and it may have formed by reaction between previously crystallized garnet and the residual liquid. However, owing to their idiomorphism, a greater possibility is that the garnet and felspar crystallized from the magma almost contemporaneously, with garnet slightly preceding felspar, which shielded it from the remaining constituents of the magma.

In a gneiss from the Mogok region of Burma, J. A. Dunn (1932) described similar garnet-cordierite-hypersthene structures which were thought to represent products of solid diffusion without participation of a solution phase. He suggested that already existing cordierite was essential to the process and that vermicular intergrowths in the cordierite corona were evidence of the mechanics of silica transfer. However, the dactylites associated with the garnets of the Violet Town Dacite are not true intergrowths and cordierite is secondary after garnet. Hence despite their similarity, it is apparent that the nature of formation was different.

Any theories advanced to explain the garnet coronas and associated dactylites must consider the following:

(i) The garnets are immersed in an extremely recrystallized groundmass of high potash and silica content.

(ii) The garnets are unstable in contact with the groundmass but stable against plagioclase felspar.

(iii) The difficulty in distinguishing between the results of solid and pore solution diffusion.

It is assumed that garnet crystallized from magma which had assimilated alumina, under conditions of high pressure. On extrusion of the still differentiating and contaminated magma, garnet became unstable in an environment of low pressure and increasing silica content, whereby it was replaced by a mineral with a smaller ferromagnesian to silica ratio (cordierite). The dactylites and outer hypersthene rim may have formed under slow conditions of cooling in the abundance of mineralizers, but still a greater possibility is their formation as a result of metamorphism by later granitic intrusions. In both environments the dactylites represent solution channels through which migration (diffusion) of material took place and the hypersthene granules are the residue from the breakdown of garnet to cordierite. Material (hypersthene?) in some of the clear dactylites is evidently where obstruction of the migrating solutions took place.

If the stability of garnet is determined by the excess of silica (beyond the requirements of the crystallizing ferromagnesians and felspars) rather than a pressure reduction, then in order to establish chemical equilibrium the number of outward migrating Fe and Mg ions in the garnet structure would be balanced by

an equal number of inward migrating silica ions. This theory would explain the directions in which the cordierite and hypersthene rims increase their width. On the metamorphic theory the kinetic energy of the Fe and Mg ions in the garnet structure is increased by the elevated temperature and this energy may exceed the migration energy for these ions, thus liberating Fe and Mg ions from their co-ordination and allowing them to migrate to other structures, cordierite and hypersthene. In this respect the dactylites represent the transfer of Fe and Mg ions from a dispersed phase to a solid structure.

The close association of dactylites with any one cordierite crystal in the inner rim suggests that the dactylites may represent the exsolved portions of an unknown solid solution. However, their radial projection from the garnet borders suggests relationships with the outer hypersthene rim and the migration theory is thus preferred.

Hence it appears that pyrogenetic garnet is rendered unstable when pressure decreases and silica content increases, and where plagioclase "shields" are absent it breaks down to cordierite. Later metamorphism of the dacite by granitic intrusions enable Fe and Mg ions liberated from the unstable garnet structure to migrate to regions of lower chemical activity, where dactylites and an outer hypersthene rim are formed. From this aspect the two-ply coronas after garnet in the Violet Town Dacite are not strictly synantectic products, and moreover they illustrate the importance of the geological environment in their formation. The amounts of secondary (metasomatic) hypersthene and cordierite formed in the dacite from the breakdown of garnet is subordinate compared with the pyrogenetic hypersthene and cordierite, and that the formation of much hypersthene-cordierite bearing calc-alkali rock by this process is extremely doubtful.

The garnet-cordierite and hypersthene-anthophyllite-biotite trends are both responses to the increasing alumina and silica content of the magma.

Cordierite and Its Alterations

Cordierite is present in all members of the Strathbogie Igneous Complex. Its presence in the Violet Town Volcanics is significant, since it is an important constituent of the acid members of the Victorian Upper Devonian lavas. Its mode of occurrence and alteration products in the various members are listed below.

Baker (1940) described cordierite from Terip Terip Granite and recognized it in the related Strathbogie Granite. Cordierite's alteration products have received

Member of the Complex	*Mode of Occurrence*	*Alteration Products*
1. Rhyolite	Completely altered phenocrysts	Chlorite and serpentine
2. Granodiorite porphyrite	Subhedral phenocrysts	Pinite and associated yellow isotropic product
3. Quartz-biotite-hypersthene dacite	Anhedral phenocrysts, some embayed with orthoclase or as a garnet reaction rim	Yellow isotropic product; spinel and sillimanite; rare pinite, serpentine and sericite
4. The granites, aplites and leucocrates	Subhedral phenocrysts	Pinite with rare isotropic product.
5. Quartz-biotite-cordierite hornfels	Xenocrysts	Turbid product, biotite and pinite.

a great deal of attention in the past, especially by Tattam (1925 and 1929) and later by Baker, who mentions that "part of the pale greenish-yellow coloured products . . . . is isotropic". Hills (1932) also mentions an "almost isotropic green chlorite" in pinite pseudomorphs. This material appears to represent the initial alteration of cordierite prior to pinitization and thus predominates in the dacite, as quicker cooling of the lavas prevented complete alteration of cordierite. Slower cooling and an increase in potash and water content favoured a more complete alteration (i.e. pinitization) in the granitic rocks. The isotropic product varies in colour, mainly in various shades of yellow and a turbid grey-brown, and possesses a refractive index less than that of cordierite.

The exothermic decomposition of cordierite is regarded as occurring late in the crystallization period, where alkaline bearing solutions are abundant. In this respect the rarity of micas after cordierite in the dacite is puzzling in view of the high potash content of the groundmass in which cordierite is immersed. Shielding effects of minerals, rapid solidification of the magma, or dry conditions of formation may contribute to this fact.

The precipitation of sillimanite and spinel in the core of some cordierite phenocrysts in the dacite is probably evidence of solid diffusion or reaction through the medium of aqueous pore solutions which were initiated by a local deficiency in silica. Tattam (1924) has noticed this cordierite alteration where liberated quartz has been apparently melted off, and in a more complex case Dunn (1932) favours solid diffusion of garnet molecules through cordierite where they react with sillimanite to form spinel-cordierite intergrowths.

The presence of cordierite in the Victorian igneous rocks is regarded as indicative of a contaminated magma (Tattam 1925, and Baker 1940). The widespread occurrence of cordierite phenocrysts in the Violet Town Volcanics suggests crystallization from a magma greatly enriched in alumina, owing to assimilation of argillaceous sediments. The apparent restriction of cordierite to marginal granite facies suggests derivation from cordierite hornfels in the wall rock.

Petrogenesis

The petrogenesis of the Upper Devonian granodiorite-dacite suite of Victoria was first suggested by Edwards (1935) as an example of differentiation of Kennedy's primary tholeiitic magma type. In more detail, Edwards (1937) provided evidence for a bigeneric process, in which assimilation of "preheated and possibly fused granitic and alumina-rich sedimentary layers" and fractionation or differentiation of the basaltic magma were responsible for the formation of the various members (rhyolite to quartz diorite) of the calc-alkaline provinces. A modification of this theory is necessary according to recent evidence supplied by Hills (1952). The sequence (rhyolite, granodiorite porphyrite, dacite, granite and aplites) of the Strathbogie Igneous Complex agrees with any theories of differentiation.

In order to explain the slightly greater silica content in the older dacite when compared with the younger granite, Summers (1922) maintained that prior to its extrusion differentiation was more advanced in the volcanic phase and that subsequent differentiation and solidification of the granite took place in a shorter period. The basal rhyolite is evidently the earliest differentiate which was "tapped" prior to roof foundering and consequent large-scale assimilation, initiated by the close approach to the surface of the granodiorite-porphyrite. Moreover, the

similarity between the composition of the granodiorite-porphyrite and the quartz-biotite-hypersthene dacite, and the presence of unstable hypersthene in the granodiorite-porphyrite, support the fact that the emplacement of the bulk of the magma, in the form of the dacite, must have followed immediately after the intrusion of the granodiorite-porphyrite, as hypersthene had already commenced to crystallize in the granodiorite-porphyrite.

The widespread and uniform occurrence of hypersthene, garnet and cordierite in the Violet Town volcanic province provides evidence for assimilation of large quantities of alumina and suggests thorough mixing of very large masses of contaminated magma. That such assimilation had commenced in the early stages of differentiation is apparent by the occurrence of occasional pyrogenetic garnet in the rhyolite. In the light of this theory, the Strathbogie Igneous Complex represents a more advanced stage in the differentiation and crystallization history of the basaltic magma than is represented in other Victorian dacite-granodiorite provinces. Because of the slow approach of the basaltic magma towards the surface, crystallization and differentiation had been active for some time. The effect of slow crystallization (intratelluric) upon the early formed minerals in an environment of reduced pressure, increased alumina, potash and silica content is revealed in their pseudomorphs and corona structures. The silicate structure of the ferromagnesians readjust themselves to these conditions. The single chain metasilicate hypersthene is replaced by the double chain metasilicate anthophyllite, and garnet is replaced by cordierite, the degree of such replacement depending upon the rate of cooling and on the degree of metamorphism, which later modifies the original cordierite corona. Chilling at the base of the dacite has prevented any reaction of early formed hypersthene and garnet with the residual magma.

Structure

The structure of the complex is based upon the following observations:

(i) The recognition of rhyolite in its various structural environments in the Violet Town volcanic province, assuming that all these structural indicators belong to the one basal flow.

(ii) The existence of the original sedimentary platform as sedimentary inliers and numerous pebbles along the contact zone between the Violet Town Dacite and the Strathbogie Granite.

(iii) The concentration of late stage granitic intrusions in the granite-dacite contact zone. The intrusions occur either alone or with the inliers, in which case they lie on the granite side of the inliers.

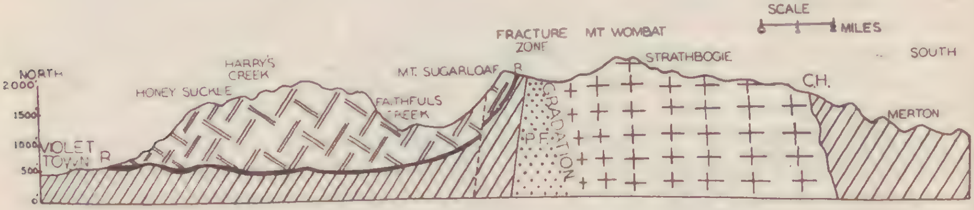

FIG. 3.—North-south sketch-section of the Strathbogie Igneous Complex. Legend and symbols as in Fig. 1. N.B.: For simplicity the granodiorite porphyrite in the depression at the foot of Mt. Sugarloaf is omitted and the Q-B-H-dacite is shown as an extrusive, which is not strictly correct (see text).

(iv) The large depression in the vicinity of the granodiorite porphyrite in the volcanic province.

The rhyolite outcrops with a low southerly dip in a limited area in the north, but it is mainly represented by xenoliths in the base of the dacite along the northern edge of the province and intermittently along the western and eastern edges. Rhyolite reappears at Mt. Sugarloaf as a sheared rock resting against sedimentary inliers with a steep northerly dip. Elsewhere along the granite contact rhyolite occurs as microcataclastic xenoliths in the recrystallized dacite. It is apparent that the rhyolite is continuous at the base of the quartz-biotite-hypersthene dacite and that it represents an assymmetrical syncline or basin with its steep limb in the south either against sedimentary inliers or granitic intrusions. The attitude of the rhyolite reflects the attitude of the bedrock formed probably in the following manner:

(i) Extrusion and solidification of rhyolite on an uneven sedimentary terrain.

(ii) Shallow intrusion of granodiorite porphyrite reaching the surface at a few places.

(iii) Owing to the proximity of the granodiorite porphyrite to the surface, the roof foundered and a general subsidence of large blocks was produced, especially along the southern edge, where drag along this main fracture sheared the rhyolite and caused it to dip steeply.

The depression in the vicinity of the granodiorite porphyrite and the steep dip of the rhyolite on Mt. Sugarloaf suggests that this region marks the position of major roof collapse. The actual mechanism of the granodiorite porphyrite intrusion is difficult to ascertain. Stoping is not apparent as bedrock xenoliths are absent and the porphyrite has been metamorphosed by the dacite. It is probable that the granodiorite porphyrite represents the approach of a differentiating magma to the surface and that it found its way to the surface through a subsidiary fracture, which was later on accompanied by further fracturing and roof foundering on a larger scale. In this manner the bulk of the magma was extruded as the widespread quartz-biotite-hypersthene dacite on to the subsided rhyolite basement. The abundance of granodiorite porphyrite schlieren throughout the dacite suggests that the porphyrite and the dacite were emplaced through a common channel. Also, the increase in hornfelsic xenoliths towards the sedimentary inliers and to a lesser extent towards the bedrock suggests that, after the major roof collapse, magmatic stoping was important. Although Summers (1922) believed that the yet undiscovered existence of the Palaeozoic platform between the dacite and granodiorite at Macedon was sufficient and conclusive evidence for overhead or magmatic stoping, its presence in the contact zone at Strathbogie has more significance. The platform remnants are evidence of roof collapse along annular fractures and that stoping was of only secondary importance, consequent upon the development of such fractures and roof foundering. Some stoping would be expected along these fractures as they are planes of weakness. Moreover, the annular shape of the granite-dacite contact and the approximate circular pattern of the Violet Town volcanic province is highly suggestive of subsidence of crustal segments on annular fractures. Although the dacite shows intrusive characteristics along the fracture contact zone with the granite in the south, and the outlying patches of dacite to the north of the main volcanic province may represent another 'intrusive edge', evidence along the western and eastern edges is insufficient to postulate the formation of a ring fracture in the emplacement of the Violet Town Volcanics.

The intrusive and extrusive characteristics of the dacite, its widespread distribution and the gradational tendencies between members throughout the province are features expected in large-scale roof foundering. Reduced pressure conditions in the magma chamber would favour the development of fractures in the roof. That such conditions prevailed at the time of the emplacement of the quartz-biotite-hypersthene dacite is evident by the breakdown of garnet to cordierite in the dacite.

The area of late stage granitic intrusives on the southern side of the sedimentary inliers supports the hypothesis that the contact between the Violet Town Volcanics and the Strathbogie Granite represents a line of weakness in the original surface structure, along which large-scale movement has taken place. The late stage granitic intrusions preferred intrusion along this fault zone rather than their usual forceful injection into the previously consolidated granite.

The homogeneous nature of the Strathbogie Granite over a wide area (approximately 430 square miles), except for occasional large tourmaline aplites, the absence of sedimentary xenoliths and restriction of cordierite-bearing granite to the periphery of the intrusion suggest that magmatic stoping played only a minor role in its emplacement. The circular pattern of the southern and western boundaries of the Terip Terip Granite, which is continuous with the Strathbogie Granite, and the occurrence of annular "embayments" of Silurian sediments along this edge suggest emplacement by the mechanism of cauldron subsidence. Since the northern boundary of the Strathbogie Granite is bounded by a pre-granite fault, the cauldron subsidence theory would be strongly supported if a similar fault could be proved along the southern boundary of the granite where the trend is linear and approximately parallels the northern boundary.

Age and Comparison with Similar Provinces

David (1950) considered plutonic intrusions, which are preceded by comagmatic hypersthene-bearing porphyries and porphyrites and which have introduced little or no important ores, as late Middle Devonian in age. Moreover, from evidence supplied by Summers (1908 and 1914), David cited the Strathbogie Igneous Complex and the related Tolmie Igneous Complex as typical examples of such intrusion. Again, he mentions the striking similarity "in character and environment" between the Marulan composite bathylith in the Goulburn district, N.S.W. (Woolnough, 1909) and the Strathbogie Complex, apparently including the Tolmie Complex as well. However, there are no known Middle Devonian intrusions in Victoria, and their Upper Devonian age is based on definite fossil evidence in combination with petrological and physiographical relationships (Hills, 1929 and 1931). From this point of view, the remarkable similarity between the quartz-biotite-hypersthene rhyodacite in the Cerberean Ranges, the quartz-biotite-hypersthene dacite in the Black Spur area and in the Violet Town Volcanics, where no interbedded fossiliferous sediments are present, must be evidence in favour of an Upper Devonian age for the Strathbogie Igneous Complex.

The Tolmie Complex has been shown to be pre-Lower Carboniferous and it has been linked petrologically with the post-Silurian Violet Town Volcanics. There are considerably more flows in the Tolmie province and, although they include some dacites, the flows tend to be more alkalic. The numerical and chemical differences between the members of the two complexes may indicate structural variations, which in turn would reflect their mode of emplacement rather than being evidence for differences in age, as from the above discussions the two

CORRELATION TABLE OF VICTORIAN UPPER DEVONIAN GRANODIORITE-DACITE SUITES

		Cerberean Ranges (Thomas, 1947)	*Black Spur* (Edwards, 1932)	*Mt. Dandenong* (Morris, 1913)	*Macedon* (Skeats and Summers, 1912)	*Strathbogie Igneous Complex*
EPI-UPPER DEVONIAN SERIES		Acid Ring Dykes (Granodiorite Porphyrite)	Granodiorite	Granodiorite	Granodiorite	Granite
UPPER DEVONIAN SERIES	Upper Acid Group (3,000 ft.)	Quartz-biotite-hypersthene Rhyodacite Nevadite-Toscanite Nevadite	Hypersthene Dacite Quartz-biotite-hypersthene Dacite Quartz Dacite	Hypersthene Dacite Middle Dacite Lower Dacite	Hypersthene Dacite	Quartz-biotite-hypersthene Dacite (?) Granodiorite Porphyrite Rhyolite
	Middle Acid Group (500 ft.)	Fragmental Toscanites Dark Rhyolite		Upper Toscanites Lower Toscanites		
	Basic Group (550 ft.)	Basalts with Pyroclastics Sediments and Ash Beds				
	Lower Acid Group (950 ft.)	Tuffs Rhyodacite Rhyolite				
		Basal Conglomerate			Basal Conglomerate	

complexes must be very closely related and must belong to the same period of igneous activity.

A correlation table has been compiled of well-known Upper Devonian granodiorite-dacite suites on the basis of the detailed sequence of the Cerberean Ranges (Thomas, 1947). Although related to the Upper Devonian igneous activity, the South Blue Range Group, the Tolmie Igneous Complex, the Mt. Wellington and dacites and comagmatic plutonic intrusions are rare or absent in the related Jemba Rhyolites are not considered in the tabulated sequence. Hypersthene-bearing occurrences, and in general they are more alkalic. Hence it may be either that evidence is forthcoming for a calcic and a potassic magma with different ages (Melbourne Handbook 1935), or that the apparent contrast in chemical composition indicates the different modes of extrusion from a common magma.

The granodiorite porphyrite is definitely pre-quartz-biotite-hypersthene dacite and although a granodiorite porphyrite is related to a similar dacite at Black Spur, the two porphyrites have little in common. The granodiorite porphyrite in the Strathbogie Complex and the hypersthene porphyrite at Tooborac (Singleton, 1949) are similar in that they contain hypersthene and are pre-granite. Ring dykes of granodiorite porphyrite are common around the northern edge of the Cerberean Ranges, where according to Hills (Thomas, 1947) this dyke is younger than the Upper Devonian lavas and represents the main channel through which the lavas were extruded. The granodiorite porphyrite has also an important structural significance in the Violet Town Volcanics, but not in the same manner as the porphyrite in the Cerberean Ranges.

The Strathbogie Igneous Complex reveals the following important features in comparison with other Victorian granodiorite-dacite provinces:

Similarities	*Dissimilarities*
(i) The dacite has a highly potassic groundmass which is more apparent in the recrystallized types.	(i) The absence of pyroclastics, fragmental toscanites and basic members.
(ii) Hypersthene, garnet and cordierite are common in the acid members.	(ii) The fewer dacite and porphyry flows.
(iii) Rhyolite is usually at the base of a group or formation.	(iii) The presence of a structural weakness (fracture) between the volcanic and the plutonic provinces.
(iv) The province possesses calc-alkaline affinities.	(iv) The presence of a granodiorite porphyrite older than the dacite.
	(v) The coarse texture of all members.
	(vi) The minute thickness of the rhyolite.

The overall significance of the diversities reflects variations in the emplacement mechanism rather than affording evidence for any variation in age between the Victorian granodiorite-dacite provinces.

Edwards (1932) assumed that the difference in intensity of metamorphism between Victorian granodiorite-dacite contacts was a function of the degree of 'de-roofing' or depth of erosion in the contact zone. It is evident from the study of the Strathbogie granite-dacite contact that the mode of intrusion is an important factor besides temperature and thickness of the dacite penetrated by the granite.

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Description of Plates

Plate IV

Fig. 1.—Hypersthene (centre) partially replaced by anthophyllite, which is surrounded by a narrow rim of green-brown biotite in the quartz-biotite-hypersthene dacite. × 10.

Fig. 2.—Anthophyllite pseudomorph after hypersthene in Q-B-H dacite. Note apatite, zircon and iron ore inclusions of the original hypersthene maintained by the anthophyllite. Also a narrow rim of biotite surrounding anthophyllite. × 10.

Fig. 3.—Unstable garnet in Q-B-H dacite. The garnet is surrounded by a continuous inner rim of cordierite and dactylites and a narrow discontinuous outer rim of hypersthene granules (H). × 10.

Fig. 4.—Unstable garnets in Q-B-H dacite. The upper garnet (G) has been almost completely replaced by cordierite, dactylites and hypersthene (H). Half of the garnet at the bottom of the photograph is unstable and partially replaced by cordierite, etc., but the remainder is stable since it is "shielded" from the groundmass constituents by felspar (F). × 10.

Plate V

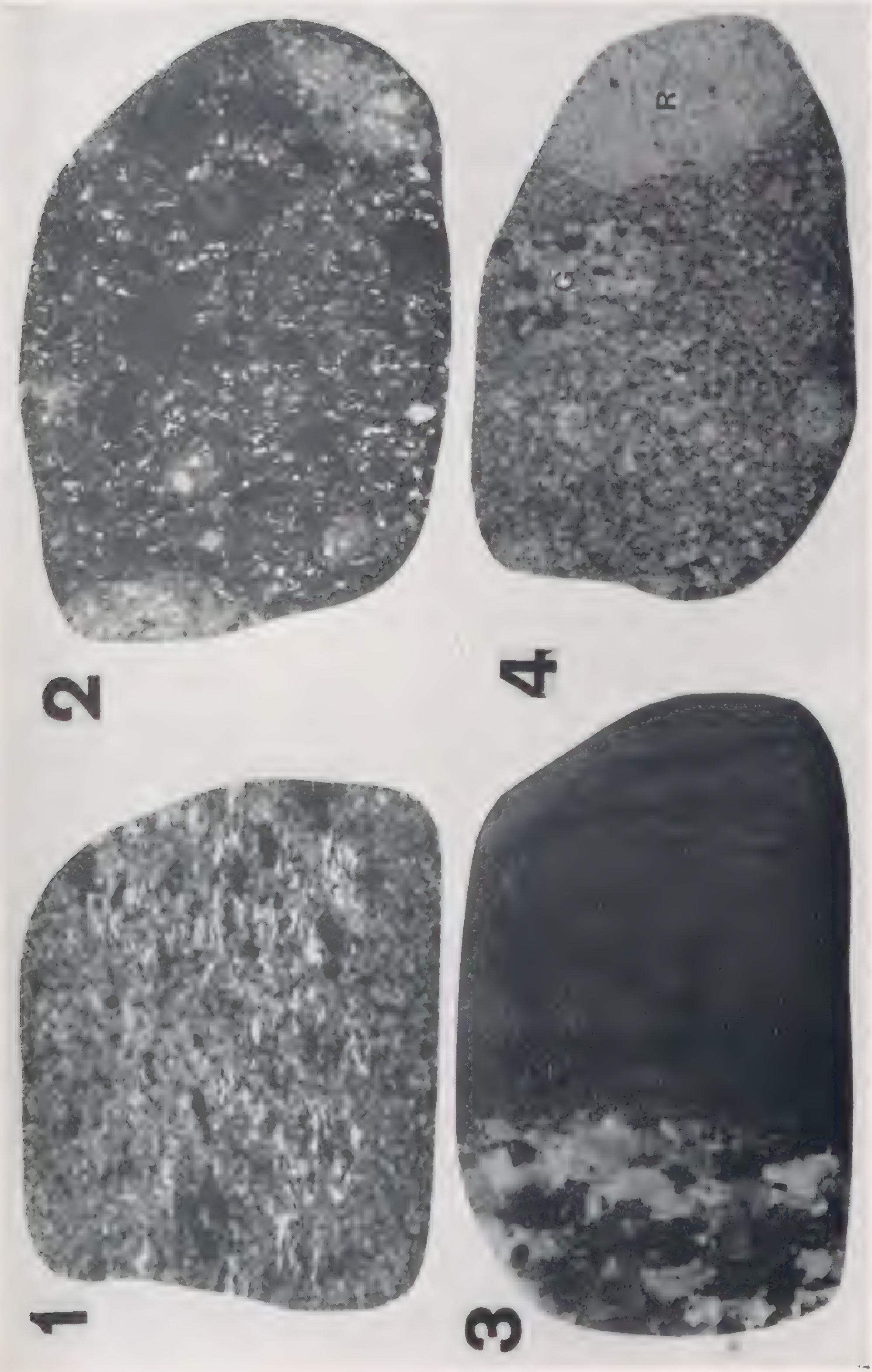
Fig. 1.—Coarse acid schlieren (granodiorite porphyrite) in Q-B-H dacite. × ¾.

Fig. 2.—Contact breccia at base of Q-B-H dacite. Note rounded rhyolite xenoliths (white) containing garnet, and angular bedrock xenoliths (black). × 1.

Fig. 3.—Contact between the Strathbogie Granite and the Silurian sediments in the south of the complex. Note preservation of crossbedding in hornfels within one inch of the granite and a narrow band of cordierite (grey dots) hornfels nearest the granite. × 1½.

Fig. 4.—Rhyolite (R) and granodiorite porphyrite (G) xenoliths in Q-B-H dacite along the eastern part of the fracture contact zone between the Violet Town Volcanics and the Strathbogie Granite. × ½.

(Photographs: D. A. White.)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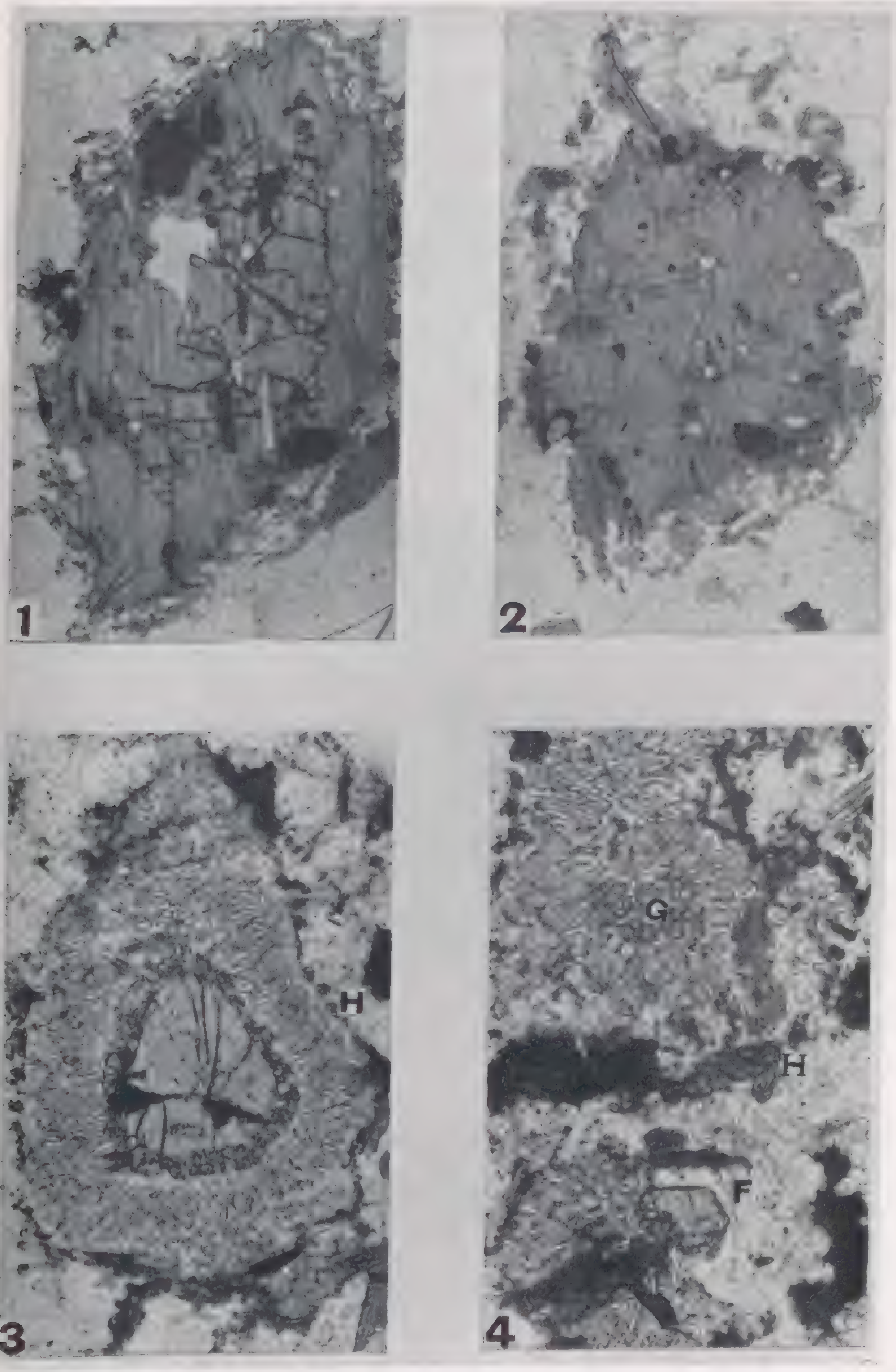
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4

UPPER MURRAY RIVER AND OPPOSED DRAINAGE SLOPES

By R. A. Keble

[Read 9 July 1953]

Abstract

The Murray River has formed in what is termed the Murray Gutter where the southerly drainage slope of the Middle Eocene Tumbarumba Creek on the Munderoo Plateau became opposed to the northerly slope of the Upper Murray developed subsequently on the Murray Uplift. The Murray Gutter is believed to be the land form underlying the development and direction of the Murray. The Kosciusko Uplift extends into Victoria and is taken to have been in the first place a tectonic uplift forming a drainage divide that has, as the Great Dividing Range, moved northwards or southwards by the headward erosion of north or south flowing streams. This tectonic uplift is conceived to have been a low arching of the base-rock, the north limb of the arch extending to the Murray flows. Previous to the arching the drainage fell southwards but after it the drainage slope was reversed and the Mitta, Kiewa, Ovens and other streams became northerly or north-westerly flowing streams.

The Murray River is taken to be the stream that has its source at Forest Hill and separates Victoria from New South Wales. On some maps, for example the 8-mile map of Victoria, the Swampy Plain River is shown as the Murray; here that river is regarded as a tributary of the Murray. Here, too, the age of the basaltic lava at Tumbarumba where it has dominated the shaping of the stream system is taken to be Middle Eocene. There is in the Tumbarumba district no palaeontological evidence to establish this but its extrusion is assumed to have been contemporaneous with that of the Older Basalt of Victoria, the age of which has been deduced from contiguous marine beds. Elsewhere (Keble 1950) the author has given his reasons for assigning a Middle Eocene age to the Older Basalt and believes that palaeontological evidence indirectly associated with its occurrence may ultimately prove it to be even older. Whatever age it is found to be, the physiographical and other facts stated here can be adjusted to the emendation.

It is proposed to discuss in some detail the origin and development of Tumbarumba Creek and incidentally the Murray, the trunk stream which Tumbarumba Creek joins and which has contributed largely to the vast accumulation of Holocene and Tertiary sediments over which the Murray flows downstream from Yarrawonga. It is apparent that downstream we have a stream of Holocene or Tertiary age but upstream the Murray has cut its channel into base-rock and been doing so while the lower reaches were being covered.

Munderoo Plateau

The valley occupied by the Tumbarumba basaltic lava was eroded on the Munderoo Plateau. Use of the term plateau arises from the view one obtains of its elevation from the Murray valley: its surface is some 1,700 feet above the Murray flood-plain. The plateau formerly extended on both sides of what is now the Murray valley before part of it south of the valley was uplifted to form the foothills leading to the Kosciusko Uplift. This uplift was partly responsible for the development and direction of the hitherto non-existent Murray.

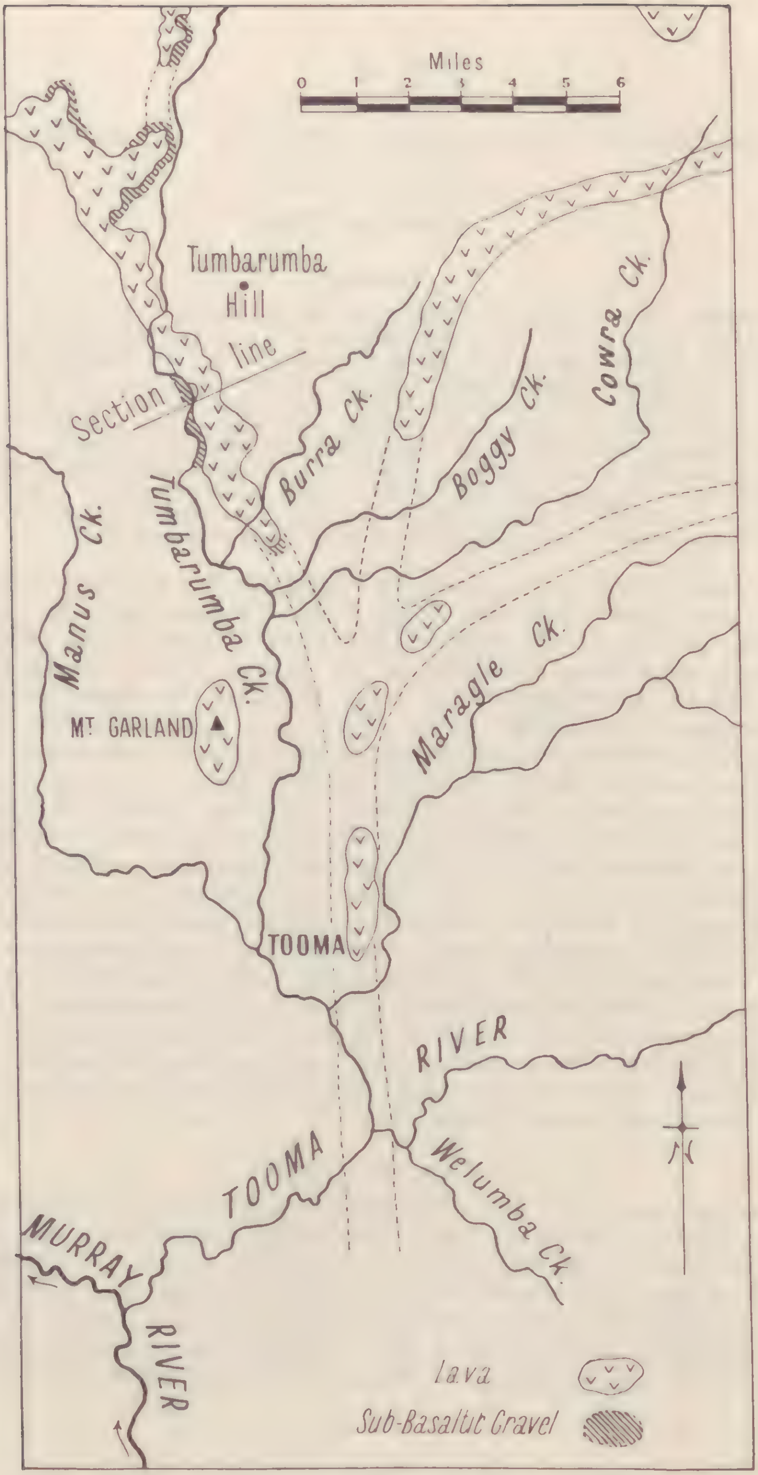

FIG. 1.—Map of Tumbarumba basaltic lava and Tumbarumba Creek, its Marginal Stream.

In reality the surface of the Munderoo Plateau is a more or less modified survival of the pre-Middle Eocene basalt land surface. Viewed from the vicinity of Munderoo, north of the Murray, where its surface is seen in an approach to its original state, it appears as a gently undulating tract of subdued topography extending south from a sinuous watershed nine miles north of Tumbarumba—a watershed that trends west and separates the Murray from the Murrumbidgee drainage systems, then south-west separating the Murray system from the westerly flowing Billabong Creek system. On the south side of the Murray its surface has been deeply dissected by streams flowing north from the Kosciusko Uplift.

Its average elevation is about 2,400 feet above sea-level but isolated eminences rise to over 3,000 feet. It slopes very gradually to the west; 60 miles to the west on the Victorian side of the Murray its average elevation is about 2,100 feet but on the New South Wales side about 1,200 feet. The S.S.E. direction of the flow of basalt in the Tumbarumba Valley as well as its marginal stream shows that the plateau also had a slope to the south. Although now dissected by streams cutting back north from the Murray, the plateau retains evidence of the old southerly drainage divides almost as far downstream as Howlong, but it was well advanced towards maturity before the extrusion of the Tumbarumba basaltic lava. We can look to the Lower Eocene, possibly the Cretaceous, for the inception of the cycle that brought this about.

No basalt occurs on the south side of the Murray.

Development of Tumbarumba Valley, Tumbarumba Creek and Tributaries

The old valley infilled with the Middle Eocene basaltic lava trending S.S.W. from its source to Tumbarumba and from Tumbarumba S.S.E. (Fig. 1) is referred to here as the Tumbarumba Valley in contradistinction to the newer Tumbarumba Creek valley formed at the margin of the basalt (Fig. 2) as a marginal stream.

Basaltic lava poured down the Tumbarumba Valley and its tributaries to at least as far as Tooma, 15 miles S.S.E. of Tumbarumba (Fig. 1); incidentally, the basalt is known to extend from the head of the valley near Batlow for 25 miles. That the fall of the valley was to the S.S.E. is inferred from the fact that the basal flow of basalt is many feet lower in elevation at Tooma than at Tumbarumba; on the meagre data available it is estimated that the fall of the valley was about 15 feet to the mile. Remnants of the basaltic strip occur at short intervals from the head of the Tumbarumba valley to near the town of Tumbarumba; this portion of the valley has been cut wholly in granite. From Tumbarumba the strip is continuous along the S.S.E. course of the valley for about seven miles, but further S.S.E. its former continuity is evident in isolated residuals as far as Tooma. Between Burra Creek and Boggy Creek a relatively long strip of lava occupies a tributary. About four miles north of Tooma another apparently long tributary—the Maragle tributary—joined the sub-basalt stream from the north-west; the basalt that occupied the Maragle valley occurs now as isolated residuals. The most southerly residual is that in the Tumbarumba Valley east of Tooma (Fig. 1). The lava ends near the foothills of the Kosciusko Uplift.

Tumbarumba lava residual is one of the eastern Victorian types—one with a single marginal stream in the upper portion of the Tumbarumba Valley; it has, however, two marginal valleys in its southern portion near Tooma.

Tumbarumba Creek flows from near Batlow along the east margin of the infilling lava as far as Tumbarumba, where it crosses the lava to the west margin

of the seven-mile strip and continues as a western marginal stream as far as Tooma; four miles S.S.E. of Tooma it joins the Tooma River, which six miles W.S.W. enters the Murray (Fig. 1) where that trunk stream turns on its general westerly course. Tumbarumba Creek retains its identity as a marginal stream until it joins the Tooma River. Less than two miles S.S.E. of Tooma, Maragle Creek cuts its channel easterly from Tumbarumba Creek south of the lava residual near Tooma thence north and north-east to become the eastern marginal stream of that residual.

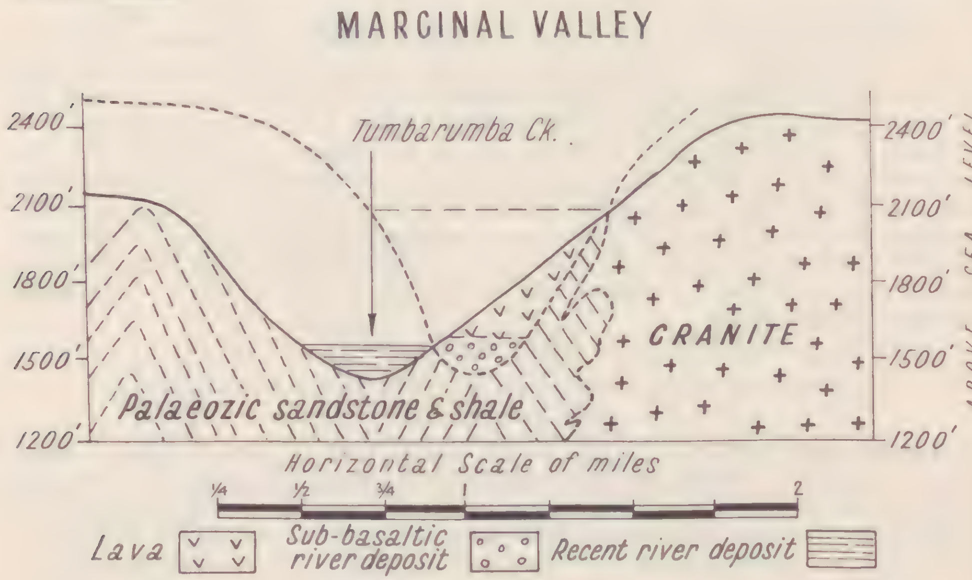

FIG. 2.—Section of Tumbarumba Lava Residual and Tumbarumba Creek marginal valley.

MURRAY GUTTER

If, before the Kosciusko Uplift, the Tumbarumba lava extended further south than Tooma (Fig. 3) it was flanked by two marginal streams flowing south, Tumbarumba Creek on its west margin and Maragle Creek on its east margin. When these marginal valleys were raised by the uplift their drainage slopes were reversed and fell to the north; as reversed streams cut deeply into the Kosciusko Uplift we know them as the northerly flowing Upper Murray and Swampy Plain River. The spur between them may be an uncovered residual (Keble 1918). One cannot say how far the lava extended, but the significant fact is that the slope of the south flowing Tumbarumba Creek is actually opposed at the Tooma River (Fig. 3) to that of the north flowing Murray. It is a commonplace to say that where the tributaries from opposite sides of a trunk stream enter at the same place their slopes are opposed, but normal tributaries enter at different angles and their directions are not approximately coincident as are those of Tumbarumba Creek and the north flowing Murray.

Where drainage slopes are opposed, such as those at the Tooma River, a gutter (to use a mining term) is formed, referred to here as the Murray Gutter

Fig. 3.—Map showing northerly flowing Upper Murray and southerly flowing Tumbarumba Creek.

(Fig. 4). As the drainage from the Murray Gutter at the Tooma River could not escape to the north or south, and to the east it was blocked by the not far distant Marangle Range, it sought its only possible outlet over the gently westward sloping Munderoo Plateau.

This juxtaposition of drainage slopes appears to be the land form that regulated the general direction and development of the Murray downstream from where the Tooma River joins it to at least as far as Yarrawonga.

Orientation of Axes of Lava Residuals and Old Drainage Direction

Orientation of the axes of the Middle Eocene lava residuals both in Victoria and New South Wales affords some indication of the direction of the old sub-basalt

streams; this was southward or at some departure from south. Any deviation from this general direction of the drainage was to avoid some local physical barrier or of a tributary, but sooner or later it found its way into a southward trending channel. Sub-basalt gravels tunnelled into may confirm this approach to a meridional trend, but evidence of this kind is qualified by the small extent of gravels usually penetrated; nor can the effect of tilting, such as has occurred at the Bogong High Plains lava residual, be discounted. Nevertheless such evidence may be reliable, for instance the S.S.W. and S.S.E. directions of fall of the Tumbarumba Valley and sub-basalt gravels.

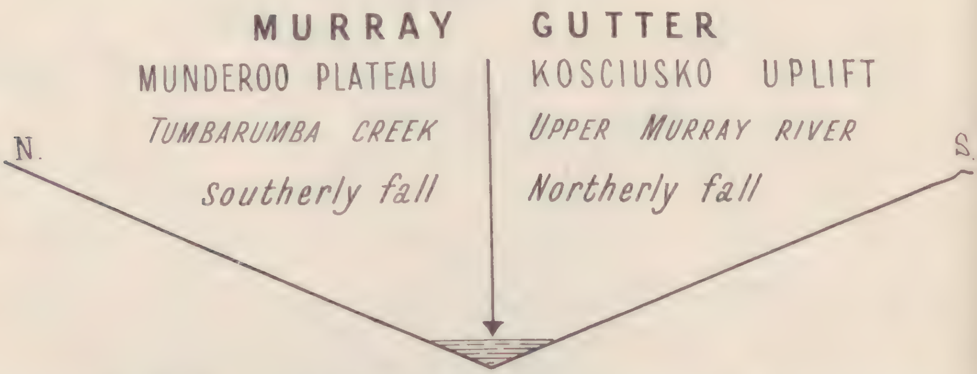

Fig. 4.—Diagrammatic Section showing Murray Gutter formed where slope of Tumbarumba Creek on Munderoo Plateau is opposed at Tooma River to that of the Upper Murray on the Kosciusko Uplift.

It may be submitted that the approximate meridional trend of the axes could indicate a northward or some departure from north trend, but the sub-basalt slope south of the Dividing Range is, apart from local deviations, southward. Moreover, the lava has resisted denudation where it covered the gravels of a major stream; it is to this fact that it owes its preservation.

Granting then a southward trend for the old Middle Eocene drainage as well as for the marginal streams that in Victoria emptied into an Eocene sea covering the lower portions of their valleys, the existence of which has been established by Baker (1943) and Raggatt and Crespin (1952), we are faced with the apparent anomaly of such streams in northern Victoria as the Kiewa and King (Ovens), marginal in their headwaters, flowing northwards. The Kiewa has perhaps developed throughout its length in a marginal valley, but the Mitta and lower reaches of the Ovens are in no way marginal. The Murray itself has cut its channel upstream from Yarrawonga diagonally across the Middle Eocene drainage slope and the pattern of the base-rock, which consists of normal and altered sediments, also granite more or less resistant to erosion; no part of it is marginal, nor seemingly has it been directed by faulting.

This conception of a reversal of the drainage slope predicates a tectonic origin for the watershed that now separates the northerly flowing from the southerly flowing streams of eastern Victoria—one that as a watershed has subsequently moved as the Dividing Range north or south with the headward erosion of the southerly or northerly flowing streams.

Kosciusko Uplift in Victoria

The Kosciusko Uplift extends from New South Wales into Victoria, and because it occurs on both sides of a provincial boundary it would be futile to refer to it by any other name. In Fig. 5 its axis is tentatively shown as following the existing drainage divide between the northerly and southerly flowing streams. In Fig. 5 only peaks of a higher elevation than 5,500 feet are shown—from east to west, Kosciusko (7,328 ft.) and Pilot (6,020 ft.), both in New South Wales just across the provincial boundary, and in Victoria Cobboras (6,025 ft.), Gibbo (5,764 ft.), Wills (5,758 ft.), Nelson (6,170 ft.), Bogong (6,508 ft.), Fainter (6,160 ft.), Feathertop (6,306 ft.), Hotham (6,100 ft.), Howitt (5,715 ft.) and Buller (5,911 ft.). It will be noted that these high peaks group themselves about the axis. The northern slope of the Uplift reaches to the Murray; the limits of its southern fall are indefinite but are possibly as far south as Wellington (5,268 ft.) and Tamboritha (5,381 ft.). It is problematical, too, how far west the axis extends. The surface of the Bogong High Plains lava residual is, in round figures, 5,000 feet above sea-level; both the Kiewa and the Ovens head near it, but the headwaters of the Mitta, in no part a marginal stream, have breached the axis east of the Bogong High Plains and pushed back the physiographical axis. The lava residuals near the head of the King River range in elevation from 3,300 feet to 900 feet.

On the south side of the axis all streams flow from S. to S.E., except some of the headwaters of the Mitta and Limestone Creek near Forest Hill. Some of the southward flowing streams are in parts marginal. Their direction of flow is complementary to the north-westerly flowing streams on the north side of the axis; in both directions the line of flow is approximately coincident with the strike of the Palaeozoic rocks.

On the New South Wales side of the Murray west of the Munderoo Plateau the trend of the stream system is fundamentally different from that in Victoria; it is westerly and dominated by the Murrumbidgee. Nevertheless, as far west almost as Howlong there is, particularly in the westward extension of the Munderoo Plateau, modified evidence of an old system of drainage with a southward trend.

Tectonics of Uplift

Dismissing faulting as the cause of the Kosciusko Uplift in Victoria and accepting a southward trend for the Middle Eocene drainage, it is again emphasized that a tectonic uplift is a *sine qua non* in understanding a reversal of the drainage slope.

Murray (1887) shows in a section through the Kiewa Valley the surface of the Bogong High Plains basaltic lava at elevations from about 4,000 to 6,000 feet above sea-level and fluviatile deposits beneath the lava sloping southwards from 5,000 feet to a little below 4,000 feet. The fall of the fluviatile deposits southward is about 27 feet to the mile, and while there is no doubt that they were deposited in a southerly flowing stream, we cannot exclude the effect of tilting, keeping in mind that the Bogong High Plains are near the axis of the postulated uplift. These elevations given by Murray imply an improbable land surface at about 4,000 feet above existing sea-level or 2,000 feet above the Munderoo Plateau. He shows the south flowing stream as far north as Mt. Fainter (Fig. 5) now in the northerly drainage slope of the Kiewa; the Kiewa has obviously pushed its watershed southward. It is pertinent to this discussion how far north of Fainter the south flowing

stream extended. The lava on Fainter implies a land surface at about 6,000 feet but not necessarily the floor of the sub-basalt valley.

About 50 miles west of the Bogong High Plains, at Mt. Samaria, there are remnants of another formerly extensive lava flow at a maximum elevation of 3,300 feet and a minimum of 900 feet. The strip at the lower elevation has doubtless been down-faulted; it is in close proximity to a strip some 600 feet higher. Little is known about the Samaria sub-basalt gravels, but the lava at the higher level implies a land surface about 3,000 feet above existing sea-level or 1,000 feet above the surface of the Munderoo Plateau.

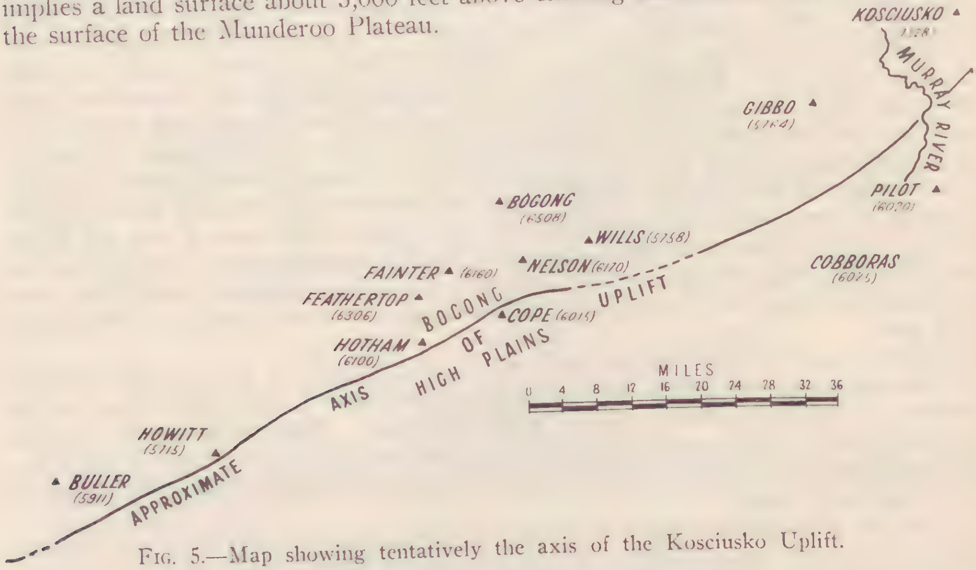

FIG. 5.—Map showing tentatively the axis of the Kosciusko Uplift.

Thus, the southward trend of the Middle Eocene drainage referred to in preliminary remarks and the S.S.W. and S.S.E. trend in the Tumbarumba Valley is corroborated by Murray in his section of the Bogong High Plains residual.

The tectonic uplift is conceived to have been caused by a low arching of the base-rock at about right angles to the general N.W. or S.E. strike. That the arch was low is evident from the fact that the angle of the northerly fall of a line from the summit of Mt. Bogong, the highest peak in Victoria, to the surface of the Munderoo Plateau near the Murray is less than a degree. The position of the arch is only tentatively shown in Fig. 5; its true position can be most convincingly located by plotting inliers in the base-rock. The inliers of older Ordovician beds near Mansfield at the western end of the axis as shown in Fig. 5 may have such a bearing. Considering the enormous amount of denudation that has occurred since the uplift, the exposure of older beds in places where there is quaquaversal dip and pitch in the base-rock is a possibility. Murray (1887) gives some idea of the excessive erosion. He states that the valley of the Dargo River, a south flowing marginal stream of the Bogong High Plains residual, has been vertically eroded to a depth of 2,800 feet below the surface of the residual. This great depth may be due to the fact that the Dargo has encroached by headward erosion into the tectonic axis. Until the tectonic axis is accurately located one cannot tell to what extent the erosional axis has deviated from it by the headward erosion of northerly or southerly flowing streams.

Briefly, it appears from the foregoing facts that such northerly and north-westerly flowing streams as the Mitta, Kiewa and Ovens have cut back on the north limb of a tectonic arch, whereas before the tectonic uplift the drainage found an outlet to the south.

Murray Gutter and Direction of the Murray

These comments on the Murray Gutter relate to its extension downstream from where the Tooma River joins the Murray (Fig. 3) to Yarrawonga. Yarrawonga is the lowest downstream locality where the Murray is still cutting its channel into base-rock and near the debouchment into the Murray of the Ovens, some of whose headwaters—King River, Boggy Creek and Fifteen Mile Creek—are marginal streams. Doubtless the Gutter extends further downstream under Holocene fluviatile deposits that filled the Gutter and spread out from it. An enormous amount of terrigenous material has been transported by the Murray and its tributaries from the highlands of Victoria and New South Wales to form the major portion of the Holocene and Tertiary cover that extends into western Victoria, New South Wales and South Australia. This transportation has taken place since the Kosciusko Uplift and the formation of the Murray Gutter, presumably since the beginning of the Oligocene; in south-western Victoria, Oligocene marine limestone is known to overlie transported sediments. Browne, Dulhunty and Maze (1944) assign a Pliocene age to the Uplift.

The Gutter was originally formed some 1,700 feet higher than the present flood-plain of the Murray at an elevation, that of the Munderoo Plateau, of 2,400 feet above existing sea-level. All tributaries except Tumbarumba Creek now entering the Murray began then to cut back to the north or south. Those from the north join at places away from those joining from the south, indicating that, apart from the north flowing headwaters of the Murray, they did not cut back in channels existing before the formation of the Gutter. All these tributaries have developed flood-plains.

The Murray was formed in the Gutter by cutting back its channel from the west, assisted perhaps in defining its channel by overflow from the opposed Tumbarumba Creek and reversed northerly flowing Upper Murray. The vertical erosion that has lowered the Murray flood-plain into its gorge was not caused by a general uplift of the Upper Murray region but by subsidence downstream, starting probably with that which brought about the marine Tertiaries. In deepening the gorge and lowering its flood-plain the river has flowed at at least six levels. It is not intended to discuss these here except to say that the highest and oldest is about 300 feet below the surface of the Munderoo Plateau and the newest or penultimate level is about 10 feet below the surface of the flood-plain.

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5

THE BASALTS AND GRANITIC ROCKS OF THE BALLARAT DISTRICT

By H. YATES, M.Sc.

[Read 9 July 1953]

Contents

Introduction

The field observations and laboratory work on which this paper is based were made over a period of more than ten years, with the assistance of an expenses grant from the University of Melbourne during part of this time.

The whole district was geologically surveyed by the pioneers of the Geological Survey of Victoria, and the outcrops of the basalts and granitic rocks are shown on the map of the Alluvial and Deep Lead Systems (Hunter, 1909, plate 4). However, no detailed descriptions of the igneous rocks have as yet been published, although chemical analyses and thin sections of some of them were made in the laboratories of the Department of Mines.

Chemical analyses of 47 basalts and also 16 granitic rocks and minerals were made by the author in the Geology laboratory of the School of Mines, Ballarat.

I wish to thank Ex-Professor H. S. Summers, Professor E. S. Hills, Mr. G. Baker, Dr. A. B. Edwards, and Mr. W. Baragwanath for valued advice and assistance during the preparation of the paper.

PART I.—Petrology of the Basalts and Tuffs

At several places in the Ballarat district sections of Cainozoic basalts or basalts and tuffs occur, comprising at least two distinct lava flows, although in some cases all the rocks of the sections are not exposed at the surface. Thus at Ballarat West,

Smeaton and other places, diamond drill boring to determine the course of the deep leads, and also shaft sinking during the mining operations, have proved the existence of four or more basalt sheets, while basalt blocks included in the outcropping tuff beds at Burrumbeet indicate the presence of several flows beneath the surface there.

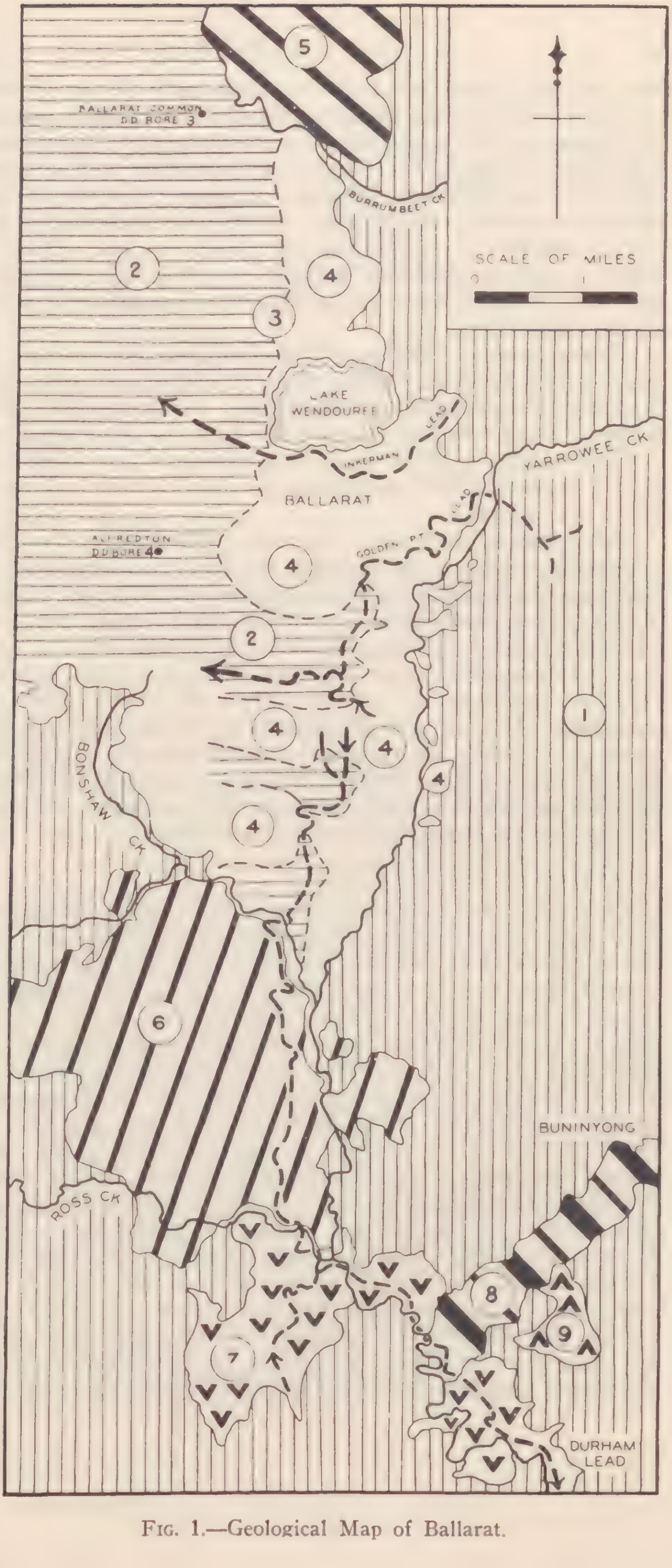
The main object of the work done was to place on record the author's chemical analyses of the basalts in the Ballarat district, and the evidence they give of differentiation in the basaltic magma before extrusion, during the inter-eruptive periods, and in the individual lava sheets after extrusion. The conclusions arrived at depend on the assumption that the various associated basalt sheets in each area were co-magmatic, and this seems justified by their limited extent and the brevity of the inter-eruptive periods as shown by the absence of thick deposits of sedimentary origin between successive sheets. One exception is the Ballarat West area, where the interbasaltic clays are up to 60 ft. thick in places, but it is probable that deposition in river lakes was rapid in this case.

In certain areas, such as Smeaton, where the several basalts were obviously extruded from different vents, though quite close together, the possibility of variable cupola differentiation must be considered, so that comparison of the rocks may lead to unreliable conclusions. This is illustrated near Ballarat where very variable alkali content of the basalts has been found within a small area comprising Ballarat West, Mt. Rowan and Warrenheip; however, in this case the different basalts do not come into the same section.

1. Basalts of the Ballarat West Area

In his work *The Ballarat Gold Field*, Baragwanath (1923, p. 51) described the extent and thickness of the basalts encountered in the mining shafts. In his first reference to them he states that there are four distinct layers, but later (p. 82) when describing the City of Ballarat Mine a fifth layer is mentioned. Actually, this is the oldest and lowest layer, being met at a depth of 367 ft. and penetrated for 30 ft. However, as it was separated from the next overlying basalt by only 5 ft. of cemented drift in the shaft, there seems some doubt as to whether it represents a distinct flow or not. Unfortunately no specimens from the shaft are available for comparison. Four distinct basalt rocks, separated by clays, were also encountered in several other shafts in the western and southern parts of the Ballarat plateau, and were shown in section by Baragwanath. The typical section showing the Ballarat deep leads is well known. Baragwanath made only very brief references to the lithological character of these basalts, but petrological descriptions of the bore cores preserved in the Geological Museum of the Department of Mines, Melbourne, have now been made and are tabulated below.

In the mining days the Ballarat West basalts were named "first rock", "second rock", etc., from the surface downwards; that is, in the order they were met in the shafts and bores. Baragwanath did not consider it necessary to alter this nomenclature, but for the purpose of the present paper the names must be reversed to correspond with the correct order of extrusion, which is more important. From the records of mine shafts it is clear that the first (oldest) and second flows are confined to the valleys of the deep leads. Their approximate extent beneath the younger sheets is indicated on the map (Fig. 1). These early flows probably issued from several separate vents because they partly filled the valleys of the Inkerman Lead, the Golden Point Lead, including the westerly extension towards Cardigan,



1. Ordovician.
2. 1st and 2nd basalts of Ballarat West, underlying the 3rd and 4th flows.
3. Approx. eastern boundary of basalts 1 and 2.
4. 4th basalt underlain by 3rd flow.
5. Mt. Rowan basalt.
6. Cambrian Hill basalt.
7. Napoleon and Durham Lead basalt.
8. Buninyong basalt.
9. Grenville Hill basalt.

Fig. 1.—Geological Map of Ballarat.

and also the Sebastopol Lead in the vicinity of the Prince of Wales mines, but were not found on the shallow ground between these leads. The third and fourth (youngest) flows issued from vents disposed along a meridional fissure in the north-west of the area. This is indicated by a low north-south ridge west of Alfredton and two low hillocks north-west of Lake Wendouree. Flowing more freely as extensive sheets they covered practically the whole of the Ballarat West and Sebastopol area, forming successive volcanic plains which sloped east and south at average gradients of 50 ft. per mile. The present surface slope indicates that the last lava sheet also flowed northwards to Burrumbeet Creek and westwards to Cardigan.

These basalts of Ballarat West terminate at Bonshaw Creek in the south, but beyond this, separate extrusions of basaltic lava occurred at Cambrian Hill and Napoleon along the same fissure line. No prominent cones were built up in the Ballarat West area like those of Mt. Rowan, Mt. Pisgah, etc., to the north.

The first three flows were each found to have a maximum thickness of about 90 ft., while the last ranges up to 160 ft. in the vicinity of its source west of Lake Wendouree.

In addition to surface outcrops, examination has been made of the core specimens from two D.D. bores in this area, one located south of Burrumbeet Creek on the Ballarat Common 2½ miles N.N.W. of Lake Wendouree, being bore No. 3 of the series drilled in 1890; the other is No. 4 of the Alfredton series (1891) located 1½ miles south-west of the lake.

The depth from which the core specimens were taken were not recorded, but they are numbered in sequence from the surface downwards. The number of specimens (15) taken to the bottom of the basalts suggests an average interval of about 20 ft., while the record of interbasaltic clays in the bore logs determines the flow to which any particular core specimen belongs. These two bore cores were selected for special study because the specimens are numerous and obviously include several from each of the basalt sheets.

Correlation of the Two Bores

The hand specimens and thin sections of the corresponding flows in the two bores agree fairly closely; so also do their chemical analyses, except for the effect of the higher H_2O and CO_2 content of the first and second flows of the Alfredton series. However, core specimen No. 11 in the Ballarat Common bore is very different, both lithologically and chemically, from Nos. 10 and 13, and may represent a separate thin flow from a different vent along the fissure. The bore details (Tables 1, 3) taken from the Annual Report of the Secretary for Mines (1890, 1892) and also the descriptions of the core specimens (Tables 2, 4) show the number of different basalt sheets in each case and how they correspond. Thus the first flow is represented by specimens 16 (Alf.) and 14 (B.C.); both are dense, fine-grained blue basalts with a black glassy base. The second flow at Alfredton (specimens 10-15) is a coarse ophitic olivine basalt which varies very little in the six samples and resembles specimens 13 and 10 of the B.C. series. It does not agree at all with Baragwanath's description "obsidian basalt" given for the "third rock" in the shaft details of the City of Ballarat mine. The three specimens 10, 11, 13 in the Ballarat Common bore correspond in depth with the second flow at Alfredton, and as they aggregate only 76 ft. in thickness and are not separated by clays, they are to be considered as a single sheet, despite the difference noted in No. 11. The third flow, specimens 3-9 (Alf.), is a dense

TABLE 1

Details of Ballarat Common D.D. Bore No. 3

Rocks pierced	Depth where struck	Thickness	Thickness of basalt sheets	Number of flow
Soil	0	8′		
Bronw vesicular basalt ..	8′	9′		
Grey basalt	17′	12′	84′ 6″	4
Blue basalt	29′	42′ 6″		
Red vesicular basalt	71′ 6″	13′		
Red clay	84′ 6″	6′		
Grey basalt	90′ 6″	15′ 6″	70′	3
Blue basalt	106′	48′ 6″		
Clays	154′ 6″	35′		
Grey and blue basalt	189′ 6″	76′ 6″	76′ 6″	2
Clay	266′	8′		
Hard blue basalt, vesicular in parts	274′	46′	46′	1
Clay and then bedrock	320′			

fine-grained blue basalt with ophitic texture in most sections. The corresponding rock in the B.C. bore (specimens 4, 5) is dark brown, due to abundant iddingsite, but it resembles the Alfredton sheet texturally and also chemically except for high Fe_2O_3 due to the iddingsite. The top rock of both bores is coarse-grained and dark brownish-grey near the surface (spec. 1) but finer grained towards the base (spec. 2).

Chemical analyses of the principal specimens preserved from the two bores are given in Tabels 5 and 6. The appreciable composition variation from flow to flow shows that differentiation of the magma took place during the interruptive periods. Comparing analysis I with the series II, III, IV (Table 6), it is evident that the first and second basalts in Ballarat West have practically the same composition despite their dissimilarity in hand specimens. Their chief chemical feature is low MgO. It is suggested, therefore, that before the commencement of vulcanicity in this area, differentiation of the magma took place, involving crystallization and sinking of olivine, so that the early lavas were impoverished in this mineral as compared with the later flows (analyses V-VIII).

In the case of the Alfredton bore, three analyses were made of each of the second and third sheets at different depths, in the hope that some definite indication of the trend of differentiation in thick lava flows might be found. However, the three analyses of the same sheet in each case are so nearly the same that we may conclude that the extent of differentiation in basaltic lava sheets up to 100 ft. in thickness, after extrusion, is negligible. The small amount of variation found does not justify the drawing of variation diagrams.

The basalts of Ballarat West are olivine-bearing basic-andesine or labradorite varieties. All the analyses by the present writer show fairly constant and low average totals of combined alkalis ($Na_2O + K_2O$) and in this respect the rocks differ from many other basalts of the district. Other chemical features worthy of note are:

(1) High Fe_2O_3 in the rocks of the Ballarat Common bore, excepting the hard fine-grained bottom rock.

(2) Lower MgO content in the earlier flows of both bore series.

TABLE 2

Description of the Core Specimens, Ballarat Common D.D. Bore No. 3

No. of core specimen	No. of flow	No. of Chem. Analysis	Macroscopical features	Microscopical features
1	4	V	Brown-black, coarse-grained	Olivine iddingsite basalt, doleritic texture. Plagioclase laths large, but augite grains small.
2	4		Brown, finer grained	
4	3			
5	3	IV	Brown-black, fine-grained but crystalline	Ophitic olivine iddingsite basalt
7	—	—	Clays from	
8	—	—	170 ft. depth	
10	2	III	Brown rock, coarse-grained, soft	Ophitic olivine iddingsite basalt
11	2	II	Blue rock, fine-grained vesicular	Fine-grained basalt with dark base, little olivine
13	2		Brown rock, crystalline	Coarse, ophitic olivine basalt
14	1	I	Blue, fine-grained, very hard	Olivine basalt with dark, glassy base

TABLE 3

Details of Alfredton D.D. Bore No. 4

Rocks pierced	Depth where struck	Thickness	Thickness of basalt sheets	Number of flow
Clay	0	9′		
Grey basalt	9′	3′		
Jointy grey honeycomb basalt	12′	26′ 10″		
Decomposed basalt	38′ 10″	4′		
Hard blue basalt	42′ 10″	44′ 1″	167′ 9″	4
Brown honeycomb and grey basalt	86′ 11″	27′ 8″		
Blue honeycomb and grey basalt	114′ 7″	7′ 11″		
Hard blue honeycomb and blue basalt	122′ 6″	45′ 3″		
Fine drift	167′ 9″	1′ 11″		
Grey clay and decomposed basalt	169′ 8″	1′ 3″		
Basalt	170′ 11″	3′ 10″		
Grey and honeycomb basalt ..	174′ 9″	18′ 9″	86′ 10″	3
Blue and honeycomb basalt ..	193′ 6″	47′		
Grey and blue honeycomb basalt	240′ 6″	16′		
Hard clay	256′ 6″	1′ 6″	91′ 3″	2
Grey, blue and honeycomb basalt	258′	89′ 9″		
Basaltic clay	347′ 9″	16′ 9″	69′ 3″	1
Honeycomb grey and blue basalt	364′ 6″	52′ 6″		
Clay and then wash	417′			

TABLE 4

Description of Core Specimens, Alfredton D.D. Bore No. 4

No. of core specimen	No. of flow	No. of Chem. Analysis	Macroscopical features	Microscopical features
1	4		Dark brown, coarse-grained	Coarse olivine-iddingsite basalt
2		VIII	Brown-black, finer grained	Medium-grained olivine-iddingsite basalt
3	3	VII	Blue, fine-grained	Olivine basalt with dark glassy base. Olivine is fresh.
4		VI	Blue, fine-grained	Ophitic olivine basalt with small amount of dark base
8		V	Blue, fine-grained	Olivine basalt with dark base
9			Blue, fine-grained	
10	2	IV	Brown-grey, crystalline	Iddingsitized olivine basalt. Medium-grained, subophitic texture.
11			Brown-grey, crystalline	Secondary carbonates and hyalite present.
12		III	Brown-grey, crystalline	,,
13			Brown-grey, crystalline	
14			Brown-grey, crystalline	
15		II	Brown-grey, crystalline	Similar to 10, with areas of brown-green glass
16	1	I	Dense blue rock, fine-grained	Olivine basalt with dark base and secondary carbonates

(3) The lower rocks of both bores, particularly at Alfredton, contain much CO_2 and H_2O due to the formation of secondary carbonates as a result of long saturation with ground water. The chief effect of this in the analyses is to give a low percentage of SiO_2.

However, if we calculate without the CO_2 and H_2O, the percentage of SiO_2 in all the basalts of the Alfredton bore is approximately 50, while in the Ballarat Common series it would range from 48 to 52. Thus the original SiO_2 content varied very little from flow to flow.

The exact composition of the secondary carbonates and their effect on the percentages of CaO, MgO and FeO are not known, but it is quite clear that they are not entirely $CaCO_3$. Their effect has been neglected in calculating the mineral percentage, and the result of this is to give somewhat high values for olivine and the pyroxenes.

Many of the analyses, especially those of the Ballarat Common bore (Table 5), and all specimens of the top rock (Table 7), show high Fe_2O_3, some of which is contained in the iddingsite. Occasionally this gives rise to normative hematite and iron-free pyroxenes and olivine which are not actually present. In view of this

and the general occurrence of both iddingsite and magnetite in these rocks, a more modative norm would be obtained by calculating one half of the Fe_2O_3 as magnetite, and the other half has hematite. Such a procedure would have the effect of increasing the amount of femic minerals and reducing the amount of normative quartz which is found in some cases. However, this suggested departure from the standard calculation has not been adopted.

TABLE 5

Chemical Analyses of Four Flows from Ballarat Common D.D. Bore No. 3

No. of core specimen	14	11	10	5	1
No. of flow	1	2	2	3	4
No. of analysis	I	II	III	IV	V
SiO_2	48.85	50.43	46.48	47.68	47.49
Al_2O_3	15.82	16.88	15.31	14.31	14.92
Fe_2O_3	.22	4.16	4.99	6.34	4.76
FeO	8.97	5.58	5.54	4.49	5.28
MgO	7.21	4.18	8.40	8.31	8.18
CaO	8.78	9.32	7.47	7.89	8.53
Na_2O	2.72	3.32	2.46	2.98	2.76
K_2O	.78	.94	.80	.94	1.02
TiO_2	2.11	1.34	1.86	2.26	2.34
P_2O_5	.28	.27	.24	.14	.21
H_2O+	1.53	1.37	2.67	1.95	2.86
H_2O-	.30	.36	3.43	2.35	2.00
CO_2	2.21	2.23	.61	Nil	Nil
Total ..	99.78	100.38	100.26	99.64	100.35
Composition of plagioclase	Ab 46	Ab 51	Ab 45	Ab 54	Ab 50
Q	—	3.48	1.31	1.14	.07
Or	4.62	5.56	4.73	5.56	6.03
Ab	23.06	28.07	20.96	25.15	23.32
An	28.58	28.36	28.21	22.88	25.27
Di	10.81	13.02	5.75	11.97	12.36
Hy	18.83	8.75	21.27	15.23	16.58
Ol	4.88	—	—	—	—
Mag	.34	6.03	7.24	7.91	6.91
Hem	—	—	—	.88	—
Il	3.95	2.56	3.54	4.30	4.45
Ap	.61	.59	.53	.31	.46
Total ..	95.68	96.42	93.54	95.33	95.45

Flows 1, 2, 3, 4: Iddingsite labradorite basalts.

Analyst: H. Yates

Variation in the Top (4th) Basalt

This basalt forms the surface rock of practically the whole of Ballarat West and Sebastopol, an area of 25 square miles. It failed to cover the Ordovician bedrock north-east of Lake Wendouree, and also near the intersection of Sturt and Raglan Streets where a small steptoe was formed. The coarse-grained doleritic texture is remarkably constant in the surface part of the sheet and the colour is generally light grey, although it is darker than usual in the cores of the D.D.

TABLE 6

Chemical Analyses of Four Flows from Alfredton D.D. Bore No. 4

No. of core specimen	16	15	12	10	8	4	3	2
No. of flow	1	2	2	2	3	3	3	4
No. of analysis	I	II	III	IV	V	VI	VII	VIII
SiO_2	46.52	46.22	44.95	45.54	49.92	50.22	50.15	48.31
Al_2O_3	14.40	14.57	15.42	13.49	15.51	15.77	15.06	15.30
Fe_2O_3	1.94	1.94	1.55	2.98	1.62	1.80	1.93	4.51
FeO	7.79	7.72	9.50	7.97	8.58	8.05	8.58	5.68
MgO	5.74	5.51	5.39	6.89	8.47	7.95	8.40	8.65
CaO	9.90	8.68	8.10	8.84	8.40	8.56	8.53	7.95
Na_2O	2.82	3.10	2.86	2.68	3.06	3.18	3.20	3.14
K_2O	.90	.80	.91	.76	.64	.78	.74	.64
TiO_2	2.22	2.14	2.18	1.73	2.25	2.32	1.92	2.17
P_2O_5	.24	.31	.31	.24	.30	.32	.27	.30
H_2O+	4.07	4.71	4.65	3.51	.85	1.11	.58	1.87
H_2O-	.26	.26	.35	1.60	.16	Nil	.32	1.80
CO_2	3.41	3.85	4.07	3.65	Nil	Nil	Nil	Nil
Total	100.21	99.81	100.24	99.88	99.76	100.06	99.68	100.32
Composition of plagioclase	Ab 54	Ab 54	Ab 49	Ab 51	Ab 51	Ab 52	Ab 54	Ab 59
Or	5.34	4.74	5.40	4.51	3.89	4.62	4.45	3.88
Ab	23.85	26.20	24.18	22.65	26.18	26.99	27.04	26.57
An	23.94	23.45	26.51	22.50	26.41	26.13	24.47	25.66
Di	19.24	14.37	9.64	16.09	10.79	11.68	13.06	9.36
Hy	8.63	11.60	10.30	13.28	17.75	15.99	14.51	18.65
Ol	3.90	3.06	8.07	3.96	6.47	5.78	8.07	1.21
Mag	2.82	2.82	2.25	4.32	2.34	2.61	2.78	6.53
Il	4.22	4.07	4.14	3.29	4.26	4.39	3.65	4.12
Ap	.53	.68	.68	.53	.65	.69	.59	.66
Total	92.47	90.99	91.17	91.13	98.74	98.89	98.62	96.64

Flows 1, 2, 3: Olivine labradorite basalts.
Flow 4: Olivine andesine basalt.

Analyst: H. Yates.

bores. The term "oatmeal rock" has been heard in reference to this basalt and is especially applicable west of Lake Wendouree where the plagioclase has tabular habit. In places augite occurs in two generations, but in other parts as fine grains only. Olivine and the iron ores are not abundant and the olivine is much iddingsitized. Slides 1542 and 1405 of the Mines Department collection show interesting textural and mineralogical variations of this rock in the form of thin layers in the main flow exposed in the Alfredton quarry. No. 1542 is relatively very coarse-grained, the augite and plagioclase crystals and also thin ilmenite rods being up to 5 m.m. in length. Zircon needles are numerous. Slide 1405 is finer grained, but has a great concentration of zircon needles and ilmenite. Olivine is rare in both these slides.

The top rock has a maximum thickness of 160 ft. in the vicinity of Lake Wendouree, and so should be most suitable for detailed study in search of variation of composition and texture at different depths. However, no specimens are avail-

able from the mine shafts, and the Alfredton bore specimens were too few to give much information in this direction, although specimen No. 2 is darker and finer grained than the top of the flow, and also has lower percentages of SiO_2 and CaO but higher MgO (cf. Analyses I, II, Table 7). Chemical analyses of the surface part of the "top rock" at several points are given in Table 7. With the exception of No. III the rocks are basic andesine- to labradorite-basalts, the composition of the plagioclase ranging form Ab_{56} to Ab_{44}. Analysis No. III is of the coarse-grained acid andesine basalt "layer" (Ab_{62}) collected by Mr. Baragwanath from the Alfredton quarry, and referred to by Edwards (1938, p. 270) as oligoclase basalt. The series of analyses shows no marked variation in the composition of the top rock in horizontal extent.

Lateral Variation of the Third Flow

Like the top flow, this earlier flow had spread over almost the whole of the Ballarat West area. In the city area proper it extended further eastwards than

TABLE 7

	I	II	III	IV	V	VI	VII	VIII
SiO_2	48.31	50.03	50.17	49.27	50.45	49.56	47.49	50.33
Al_2O_3	15.30	15.54	14.43	15.33	14.96	16.30	14.92	17.43
Fe_2O_3	4.51	5.80	8.02	8.40	6.26	3.51	4.76	5.48
FeO	5.68	5.40	3.65	4.71	4.72	6.48	5.28	3.73
MgO	8.65	6.64	7.66	3.47	6.98	7.86	8.18	6.17
CaO	7.95	9.02	8.96	7.05	8.60	9.04	8.53	8.28
Na_2O	3.14	3.44	3.04	3.54	2.93	3.42	2.76	2.88
K_2O	.64	.92	1.08	2.25	1.08	.68	1.02	.60
TiO_2	2.17	2.59	1.70	3.71	1.93	2.26	2.34	2.04
P_2O_5	.30	.33	.33	.61	.37	.35	.21	.30
H_2O+	1.87	.47	.68	.48	.79	.73	2.86	2.16
H_2O-	1.80	.51	.85	.54	.97	.28	2.00	.18
CO_2	—	—	Nil	Nil	Nil	—	—	—
Others	—	—	.28	.46	.34	—	—	—
Total ..	100.32	100.69	100.85	99.82	100.38	100.47	100.35	99.58
Plagioclase ..	Ab 59	Ab 56	Ab 55	Ab 62	Ab 52	Ab 53	Ab 50	Ab 44
Q	—	.69	2.92	4.04	4.72	—	.07	6.52
Or	3.88	5.42	6.40	13.34	6.40	4.03	6.03	3.56
Ab	26.57	29.08	25.69	29.92	24.78	28.91	23.32	24.34
An	25.66	24.21	22.51	19.25	24.44	27.13	25.27	32.82
Di	9.36	14.56	15.41	9.16	12.33	12.31	12.36	4.92
Hy	18.65	12.93	12.02	4.44	12.04	11.57	16.58	13.15
Ol	1.21	—	—	—	—	5.36	—	—
Mag	6.53	4.24	6.83	4.42	9.08	5.09	6.91	6.14
Hem	—	2.88	3.31	5.36	—	—	—	1.25
Il	4.12	4.92	3.23	7.05	3.67	4.29	4.45	3.88
Ap	.66	.72	.72	1.34	.81	.77	.46	.66
Total ..	96.64	99.65	98.04	98.32	98.27	99.46	95.45	97.24

I. 4th flow; Specimen No. 2, Alfredton D.D. bore; Analysis VIII from Table 6.
II. 4th flow; from the surface at Alfredton South near the Cattle Yards.
III. 4th flow; from near the surface at the City Quarry, Alfredton. *Analyst:* A. J. Hall.
IV. 4th flow; acid-andesine layer, from the City Quarry, Alfredton. *Analyst:* A. G. Webb.
V. 4th flow; from west bank of Yarrowee Creek Ballarat South, near old pyrites works. *Analyst:* A. J. Hall.
VI. 4th flow; olivine iddingsite andesine basalt, from the surface at Bonshaw Creek, Ballarat South.
VII. 4th flow; Specimen No. 1, Ballarat Common, D.D. bore; Analysis V, Table 5.
VIII. Ophitic olivine iddingsite labradorite basalt; from the surface at Napoleon, 8 miles south of Ballarat.

the top rock, but is now covered by thick clays east of Yarrowee Creek. It outcrops only at a few places in Ballarat South, forming low hills on the east side of the creek, and also narrow exposures along the base of the cliff where the creek has cut through the top rock. The third rock has fairly constant lithological character, being fine-grained and dense. Its colour is brownish-grey at Yarrowee Creek and light bluish-grey in the Alfredton bore (five specimens). Most samples examined of this flow are ophitic olivine andesine basalt with plagioclase, Ab_{55} to Ab_{49}. The ophitic fabric is exceptionally well developed in the Yarrowee Creek specimen. Study of the chemical analyses (Table 8) reveals considerable variation of certain important oxides in the upper part of the third rock at different places. This shows that the conditions of solidification were not uniform throughout the whole of the sheet. Thus, low MgO and Fe_2O_3 in the eastern portion of the flow indicates sinking of early formed crystals of olivine, augite and magnetite here. However, in view of the fact that several analyses of the same flow at different depths in the Alfredton bore show no marked variation of MgO it is suggested that the sinking of crystals in this case did not take place entirely *in situ*, but to a great extent progressively as the flow proceeded eastwards, so that the eastern edge of this basalt is impoverished in olivine and magnetite, although ilmenite is abundant, as shown by the exceptionally high TiO_2 content. The author's analysis of the third rock at Yarrowee Creek does not agree very closely with that made by Hall. The latter's sample was from a little further south, and the high value obtained for CO_2 suggests that it was not as fresh as possible.

Vertical Variation of the Third Flow

Three specimens of this rock from different depths in the Alfredton D.D. bore have been analysed (Nos. V, VI, VII, Table 6) and very uniform composition of the sheet is indicated. The only noticeable variation is a slight impoverishment of the upper level in ilmenite and apatite due to sinking of these minerals.

Variation of the Second Flow

Three specimens of this rock from the Alfredton bore were chosen for analysis, so that the depth intervals would be considerable (Nos. II, III, IV, Table 6). However, only minor variations of composition are noted.

The low MgO content suggests that olivine crystallized to some extent in the magma reservoir and sank before extrusion of this flow. Then, after extrusion, the lava cooled slowly, allowing the olivine constituents to become concentrated in the upper levels without forming large crystals and sinking to any considerable extent. The lower TiO_2 and P_2O_5 in the upper part of the sheet is explained by sinking of ilmenite and apatite crystals after extrusion.

A core specimen from the Cardigan D.D. bore, taken at a depth of 200 ft., corresponds in level with the second flow at Ballarat West. It is a blue vesicular olivine andesine basalt (Ab_{55}) with abundant dark glassy base. However, chemically it does not resemble either the second or first flow at Ballarat West, having a very high MgO content (Analysis V, Table 8).

2. Basalts of the Warrenheip, Gong Gong and Creswick Areas

Four miles due east of the eastern edge of the Ballarat West basalts we come to the meridional western edge of the Warrenheip basaltic plateau whose average surface altitude is 400 ft. higher than Ballarat West. The first basalt poured out

Table 8

	I	II	III	IV	V
SiO_2	50.15	47.68	51.69	46.81	49.95
AL_2O_3	15.06	14.31	15.17	12.94	14.53
Fe_2O_3	1.93	6.34	.35	1.62	2.75
FeO	8.58	4.49	7.64	8.39	8.18
MgO	8.40	8.31	4.59	6.81	8.92
CaO	8.53	7.89	8.19	9.51	8.98
Na_2O	3.20	2.98	2.80	2.76	3.16
K_2O	.74	.94	1.00	.88	.94
TiO_2	1.92	2.26	2.93	1.60	2.49
P_2O_5	.27	.14	.27	.25	.33
H_2O+	.58	1.95	1.24	.90	.10
H_2O-	.32	2.35	1.17	.50	—
CO_2	—	—	2.54	6.85	—
Others	—	—	—	.14	—
Total ..	99.68	99.64	99.58	99.96	100.33
Plagioclase	Ab 54	Ab 54	Ab 49	—	Ab 55.6

I. Upper part of 3rd flow; Specimen No. 3, Alfredton D.D. bore; Analysis VII from Table 6.
II. Upper part of 3rd flow; Specimen No. 5, Ballarat Common D.D. bore; Analysis IV from Table 5.
III. 3rd flow, from Yarrowee Creek at Prest Street, Ballarat South. It is ophitic labradorite basalt. *Analyst:* H. Yates.
IV. 3rd flow, from Yarrowee Creek at Prest Street, Ballarat South. It is ophitic labradorite basalt. *Analyst:* A. J. Hall
V. Olivine andesine basalt from 200 feet depth in the D.D. bore at Cardigan, west of Ballarat. *Analyst:* H. Yates.

in this area was the very extensive Clarke's Hill sheet which flowed away in all directions, but principally southwards, from the prominent vent $1\frac{1}{4}$ miles south of Dean. The lava flowed over an irregular granitic surface, as shown by evidence from D.D. bores at Warrenheip and three miles south of Clarke's Hill.

The adamellite outcrops near Warrenheip railway station, at Woodman's Hill and at Gong Gong Reservoirs, and in the vicinity of these outcrops the basalt is naturally thin—about 30 ft. at Gong Gong. However, thicknesses up to 200 ft. were found in the D.D. bores. The Clarke's Hill flow is still the surface rock of the greater part of the Parish of Bungaree and Dean, and of a considerable area west of Lal Lal Creek, extending from Warrenheip to Lal Lal (Fig. 2). Within a restricted area surrounding Mt. Warrenheip the Clarke's Hill flow is overlain by a second, less extensive basalt. This lava was not poured out from Mt. Warrenheip except for a small amount which flowed due north out of the breached crater in the final stage of the vulcanicity and formed a very gentle uniform surface slope. Most of it issued from subsidiary vents just west and east of the mountain and marked by low hills. From the western vents the lava flowed south, west and north-west and solidified with a steep edge trending west by north between the mountain and the railway station, then swinging northwards towards Gong Gong. To the north-west of the vent this lava crossed the western edge of the Clarke's Hill basalt and turned west down the ancestor of the present Yarrowee Creek, forming a narrow tongue half a mile long. From the subsidiary vents east of Mt. Warrenheip the lava flowed north, south and east. Its boundary has determined the course of the Two Mile Creek, west of Bungaree.

The Clarke's Hill basalt is a bluish-grey rock in which very numerous phenocrysts of olivine up to 5 mm. in length can be seen in hand specimens. There are also occasional phenocrysts of augite and glassy andesine. Its chief microscopical features are that the base is holocrystalline, and some of the olivine and augite is

1. Ordovician.
2. Granite.
3. Clarke's Hill basalt.
4. Warrenheip basalt.
5. Green Hill basalt.
6. Yendon basalt.
7. Buninyong basalt.
8. Buninyong-Clarendon basalt.
9. Mt. Warrenheip and Mt. Buninyong, scoria cones.
10. Kaolinized granite.
11. Recent alluvium.

FIG. 2.—Geological Map of Warrenheip-Buninyong area.

glomeroporphyritic. The younger Warrenheip basalt is extremely fine-grained but holocrystalline, and it too contains a few large phenocrysts of glassy andesine. The plagioclase laths are well developed, though small, the augite is in tiny grains and the olivine occurs as micro-phenocrysts of average grainsize 0·2 mm. This rock, both at Warrenheip and Gong Gong, contains corroded grains of quartz, which were probably caught up by the magma as it was ascending through decomposed adamellite. The chemical analyses (Table 9) show that the norms of both basalts contain olivine, nepheline and andesine, and both are much more alkaline than the Ballarat West series. They are closely related to the basalts of the Bullarook-Newlyn area to the north (Analysis No. V). The author's analysis of the Clarke's Hill flow does not agree with Clarke's analysis (No. II, Table 9) in which the very low percentage of MgO is incompatible with the actual mineral composition of the rock.

TABLE 9

	I	II	III	IV	V
SiO_2	50.06	48.56	46.33	48.10	47.46
Al_2O_3	14.73	19.36	17.78	17.14	16.12
Fe_2O_3	1.61	1.10	2.25	4.02	2.96
FeO	8.49	9.21	6.97	6.42	9.39
MnO	—	.09	—	—	.25
MgO	7.94	5.21	7.00	6.32	5.70
CaO	8.27	8.52	7.76	7.91	7.27
Na_2O	4.06	2.62	4.04	4.28	3.51
K_2O	1.59	1.57	2.40	2.14	1.74
TiO_2	2.62	2.13	2.85	2.71	3.10
P_2O_5	.44	.50	.71	.58	.78
H_2O+	.47	1.07	1.25	.57	.57
H_2O-	.11	.20	.34	.14	.72
Total	100.39	100.22	99.68	100.33	99.57
Plagioclase	Ab 65	—	Ab 48	Ab 57	Ab 58
Or	9.40	9.32	14.19	12.66	10.33
Ab	29.47	22.25	19.81	26.59	29.66
An	17.23	36.37	23.24	21.19	23.04
Ne	2.62	—	7.76	5.19	—
Di	17.32	2.56	8.77	11.49	6.61
Hy	—	14.02	—	—	5.10
Ol	15.47	7.62	14.04	10.25	11.36
Mag	2.32	1.67	3.26	5.83	4.29
Il	4.98	4.04	5.42	5.15	5.89
Ap	.96	1.09	1.55	1.27	1.71
Total	99.84	—	98.04	99.62	97.99

I. Porphyritic olivine andesine basalt, Clarke's Hill flow from Gong Gong Quarry. *Analyst:* H. Yates.
II. Idem. *Analyst:* J. Clark.
III. Olivine labradorite basalt, 1 mile N.W. of Mt. Warrenheip. *Analyst:* H. Yates.
IV. Idem. From Yarrowee Creek, Gong Gong. *Analyst:* H. Yates.
V. Olivine Andesine basalt from Newlyn, parish of Spring Hill. *Ann. Rep. Sec. Mines, Vic.*, 1911, *page* 62.

Other alkaline basalts occur at several prominent points of eruption in the Creswick area, namely Spring Mount, Mt. Hollowback, Mt. Pisgah and Mt. Rowan. They are porphyritic types, the phenocrysts being augite, olivine and andesine. Their analyses (Table 10) gave high Al_2O_3 and alkalis, but low MgO and SiO_2, so that nepheline appears in the norm of two of them. Augite pheno-

crysts are best developed in the Newlyn, Spring Mount and Mt. Rowan basalts, while andesine phenocrysts are very prominent in the Egan's Town, Spring Mount and Mt. Hollowback rocks.

The Mt. Pisgah basalt has small phenocrysts of olivine, augite and andesine, and contains occasional gabbroic xenoliths. The basalt at Mt. Blowhard has a coarse ophitic texture and is less alkaline than the others.

TABLE 10

	I	II	III	IV	V	VI
SiO_2	46.82	46.36	46.91	60.16	47.66	49.98
Al_2O_3	19.26	19.87	17.73	24.90	17.30	16.18
Fe_2O_3	1.79	.87	5.14	—	1.72	3.73
FeO	7.37	8.96	6.47	—	8.37	6.23
MgO	5.65	5.45	4.94	.04	7.82	7.70
CaO	7.94	7.34	6.96	7.26	8.20	8.84
Na_2O	3.68	4.02	3.60	7.24	3.52	3.08
K_2O	1.92	1.64	1.98	.94	1.24	1.12
TiO_2	2.74	2.43	2.97	—	3.20	2.12
P_2O_5	.76	.47	.53	—	nd .50	nd .50
H_2O+	1.43	1.15	1.64	—	.42	.45
H_2O-	.31	1.33	.96	—	.67	.52
Total	99.67	99.89	99.83	100.54	100.62	100.45
Comp. of plagioclase	Ab 48	Ab 46	Ab 55	Composition Or 5 Ab 62 An33	Ab 52	Ab 51
Or	11.36	9.70	11.72	—	7.34	6.63
Ab	26.13	24.84	30.43	—	28.78	26.19
An	30.31	31.27	26.32	—	27.92	26.89
Ne	2.69	4.97	—	—	.52	—
Di	3.41	1.72	3.79	—	7.78	10.93
Hy	—	—	4.18	—	—	16.69
Ol	14.51	17.96	6.53	—	17.53	1.60
Mag.	2.60	1.28	7.45	—	2.50	5.41
Il	5.21	4.62	5.64	—	6.08	4.03
Ap	1.70	1.03	1.17	—	1.09	1.09
Total	97.92	97.39	97.23	—	99.54	99.46

I. Porphyritic olivine labradorite basalt, parish of Spring Hill.
II. Porphyritic olivine labradorite basalt, Mt. Hollowback.
III. Porphyritic andesine basalt, Mt. Rowan.
IV. Potash-andesine phenocrysts in Mt. Hollowback basalt.
V. Olivine andesine basalt, Mt. Pisgah.
VI. Ophitic iddingsite labradorite basalt, Mt. Blowhard.

Analyst: H. Yates.

3. MOUNT WARRENHEIP

Mt. Warrenheip is a breached fragmental cone which accumulated on top of the Clarke's Hill basalt. It was briefly described and also figured in hachure by Gregory (1903). The summit of the mount is 2,430 ft. above sea-level, and its base is 100 ft. higher on the west and north sides than on the south and east, due to the presence of subsidiary cones along the northern and western margins. The height of the cone itself varies from 450 ft. to 550 ft. and the surface in the crater is 300 ft. below the rim. The surface gradient on the south and east slopes is approximately 30°. The cone was probably built up rapidly during a violent explosive phase which initiated the vulcanicity at this vent, and the volcano

remained active until the final effusion of a small lava stream to the north, simultaneously with the pouring out of more extensive lava from the subsidiary vents to the west. Just prior to this, however, the northern rim of the crater was breached by another violent explosion.

The fragmental materials composing the mountain include vesicular basalt, scoria, volcanic bombs, blocks of adamellite, and reef quartz. The adamellite and quartz are portions of the pre-basaltic surface rocks which were burst through by the explosions. The volcanic bombs vary in size from 1 in. in diameter to 2 ft. 6 in. in length, and there is also some variation of shape. The large majority are ellipsoidal and have protuberances at both ends of the major axis, the axis of rotation. A few small biconvex buttons with complete flanges were found, while one specimen is a biconvex disc with a tail. Many of the bombs have a kernel of olivine, often comparatively large and giving the specimen an appreciably higher specific gravity. In a few cases there is a core of decomposed adamellite, while some bombs have no kernel. The olivine kernels are cognate xenoliths but the adamellite kernels are 'strangers'. Concentric flow lines are nearly always present, indicating solidification during rotation in the air. The vesicular basalt, scoria and volcanic bombs contain sporadic granular masses of olivine, also crystals and grains of titanaugite and anorthoclase (analyses, Table 11). All three minerals were

TABLE 11

	I	II	III	IV	V
SiO_2	65.64	61.93	48.89	49.00	43.16
Al_2O_3	20.52	22.08	9.41	8.66	—
Fe_2O_3	Nil	tr.	1.78	2.78	—
FeO	Nil	—	5.83	6.52	14.14
MgO	Nil	tr.	14.38	14.53	43.08
CaO	Nil	Nil	16.80	15.64	—
Na_2O	10.36	8.84	1.14	1.12	—
K_2O	2.25	6.34	Nil	0.05	—
TiO_2	—	—	1.65	1.27	—
P_2O_5	—	—	—	Nil	—
H_2O-	—	—	0.30	0.06	—
H_2O-	—	—	—	0.14	—
Others	—	—	—	0.44	—
Total	98.77	99.19	100.18	100.21	100.38

I. Anorthoclase, Mt. Warrenheip. *Analyst:* H. Yates.
II. Glassy tabular felspar crystals from dense basalt, Magorra, near Jumbunna. *Analyst: Geol. Surv. Vic.*, 1901.
III. Titanaugite, Mt. Warrenheip. *Analyst:* H. Yates.
IV. Augite, Mt. Noorat, near Terang. *Analyst:* A. J. Hall.
V. Olivine, Mt. Warrenheip. *Analyst:* H. Yates.

undoubtedly early crystallization products of the olivine-basalt magma, and the pure lime-free anorthoclase suggests considerable cupola differentiation at this point. The mineral occurs only in small quantities, but sufficient was found for analysis and sectioning. It is quite colourless and the section shows the characteristic "cross hatch" twinning lamellae. The refractive index is lower than that of canada balsam and the optical character is negative.

The only other occurrence of lime-free felspar in Victorian basalts or associated scoria, etc., to which reference has been found is that from dense basalt at Magorra near Jumbunna (Mahoney, 1928). The augite at Mt. Warrenheip agrees fairly closely in composition with that from Mt. Noorat.

4. Basalts of the Buninyong-Mt. Mercer Area

In the Buninyong-Mt. Mercer area there were several points of volcanic eruption, chief of which from north to south are Green Hill, Mt. Buninyong, Grenville Hill, Hardie's Hill, Mt. Mercer and Mt. Lawaluk, with Cargerie Hill to the east. This series of vents is separated from Mt. Warrenheip by a five-mile belt containing no points of eruption. The small flow from Green Hill moved north-east to meet the edge of the Clarke's Hill flow at Navigator. Mt. Buninyong, two miles south-east of Green Hill, rises to the same altitude as Mt. Warrenheip. It is more composite in structure than Warrenheip, however, comprising several points of effusion in addition to the main cone which was built up of ejected fragments chiefly, including volcanic bombs. It is clear that at least two lava streams flowed from the Mt. Buninyong vent. The earliest was the Clarendon flow, which moved south and south-east. After this the main fragmental cone was formed and later breached by explosions on the north-west rim. Finally an extensive narrow lava stream flowed out of this breach, westwards at first for two miles, then south-west down a tributary valley of the Durham Lead. The small flow from Grenville Hill moved north to meet this Buninyong basalt. The basalts of the Durham Lead, between Buninyong and Mt. Mercer, were referred to at some length by Etheridge and Murray (1874) when the auriferous lead was being mined. With the aid of data from the Pioneer, Duke of Cornwall, City of Manchester and other shafts they showed that the deep narrow lead was filled by two separate lava streams for the full length of ten miles from Durham Lead to

Table 12

	Megascopical features	Microscopical features
I. Green Hill Basalt..	Blue-grey, fine grained crystalline, occasional phenocrysts of olivine augite and plagioclase	Very fine-grained, holocrystalline, with occasional phenocrysts of olivine, to 1 m.m.
II. Yendon Basalt ..	Dense fine-grained blue rock with a few phenocrysts of plagioclase and olivine	—
III. Buninyong Basalt .	Dense, bluish-grey, fine grained	Olivine iddingsite basalt, good fluidal fabric
IV. Clarendon Basalt..	Blue, fine-grained	Fine grained, holocrystalline. Microphenocrysts of olivine.
V. Grenville Hill Basalt	Blue, fine grained, crystalline with occasional phenocrysts of olivine and augite	Porphyritic augite olivine basalt, good trachytic fabric
VI. Garibaldi Basalt ..	Blue, coarse grained	Ophitic olivine iddingsite basalt
VII. Hardie's Hill Basalt	Similar to No. V	Similar to No. V
VIII. Mt. Mercer Basalt .	Blue-grey, fine grained	Fine grained, pilotaxitic basalt with microphenocrysts of olivine
IX. Mt. Lawaluk Basalt	Dark Blue, fine grained	Black glass abundant. Plagioclase laths and microphenocrysts of olivine and augite

Mt. Mercer. The first flow was 88 ft. thick and the second 113 ft. in the Duke of Cornwall shaft near Hardie's Hill.

These lavas certainly flowed southwards, and probably issued from the Napoleon and Cambrian Hill vents because the upper flow at Garibaldi, ophitic olivine iddingsite basalt, closely resembles the surface rock at Napoleon, but is quite unlike the flows from Mt. Buninyong and Grenville Hill. Coulson (1937) described the Durham Lead basalt as containing abundant oligoclase, but the actual flow referred to was not stated. At the present time no specimens of the lower sheet are available for study.

The Durham Lead basalts are locally covered by the thin flow from Hardie's Hill, but this was very limited in extent. In the vicinity of the vent it was finally concealed by beds of ash and volcanic breccia, which form a well defined rim around the large crater. Further south the narrow Durham Lead basalts pass beneath the extensive Mt. Mercer flow, which moved southwards chiefly. To the east of the Mt. Mercer flow another broad basalt sheet moved south-west from the Green Hill or Collier's Hill in the Parish of Cargerie, and the junction of these

TABLE 13

	I	II	III	IV		V	VII
SiO_2 ..	47.31	46.72	50.01	50.21	49.10	47.81	50.28
Al_2O_3 ..	16.15	18.80	16.86	17.28	16.71	15.40	17.57
Fe_2O_3 ..	5.28	1.53	5.51	3.04	3.18	6.37	4.31
FeO ..	6.53	7.29	4.96	5.98	6.80	5.61	4.96
MgO ..	6.30	6.44	3.85	4.58	7.72	7.58	3.86
CaO ..	7.84	7.72	7.38	7.52	7.90	8.48	6.98
Na_2O ..	3.54	4.56	3.42	3.80	3.55	3.94	4.08
K_2O ..	1.66	2.42	1.84	1.78	.96	1.04	1.66
TiO_2 ..	3.00	2.85	3.71	3.42	1.87	2.42	3.71
P_2O_5 ..	.43	.74	.35	.45	.29	.44	nd.35
H_2O+ ..	.96	.80	1.14	.89	.89	.91	.65
H_2O- ..	1.10	.24	.76	.88	.62	.39	1.37
Total ..	100.10	100.11	99.79	99.83	99.59	100.39	99.78
Plagioclase .	Ab 58	Ab 46	Ab 55	Ab 58	Ab 54	Ab 60	Ab 60
Q	—	—	4.48	.34	—	—	2.14
Or	9.82	14.33	10.88	10.57	5.68	6.16	9.81
Ab	29.90	19.01	28.91	32.12	30.00	33.30	34.48
An	23.21	23.63	25.17	24.77	26.78	21.23	24.69
Ne	—	10.60	—	—	—	—	—
Di	10.22	8.02	7.13	7.67	8.44	14.06	5.97
Hy	2.97	—	6.33	10.67	8.96	.15	6.89
Ol	7.56	14.21	—	—	9.39	9.36	—
Mag ..	7.66	2.22	5.23	4.41	4.62	9.23	5.23
Hem ..	—	—	1.91	—	—	—	.71
Il	5.70	5.42	7.05	6.52	3.55	4.60	7.05
Ap	.93	1.62	.77	.98	.64	1.03	.76
Total ..	97.97	99.06	97.86	98.05	98.06	99.12	97.73

I. Olivine Andesine basalt, Green Hill. *Analyst:* H. Yates.
II. Olivine nepheline labradorite basalt, Clarendon. *Analyst:* H. Yates.
III. Andesine basalt, Buninyong. *Analyst:* H. Yates.
IV. Andesine basalt, Grenville Hill. *Analyst:* H. Yates.
V. Olivine andesine basalt, Hardie's Hill. *Analyst:* H. Yates.
VI. Olivine andesine basalt, Mt. Mercer. *Analyst:* H. Yates.
VII. Andesine basalt, Yendon. *Analyst:* H. Yates.

FIG. 3.—Geological Map of the Gordon-Lal Lal area.

1. Ordovician.
2. Granite.
3. Clarke's Hill basalt.
4. Warrenheip basalt.
5. Wallace to Lal Lal basalt.
6. Iron ore deposit.
7. Post-Pliocene sands, etc.
8. Recent alluvium.

two lava fields has determined the channel of the present Leigh River which no longer follows the general course of the Durham Lead as it does further north.

The principal megascopical and microscopical characters of the basalts in the Buninyong-Mt. Mercer area are given in Table 12.

Newberry made chemical analyses of some of the basalts from the Durham Lead. They were incorporated in the Report by Etheridge and Murray, but they are unsuitable in form for comparison with the present writer's analyses (Table 13).

Study of the table shows that the basalts from the vents in the northern part of the area—Green Hill, Buninyong, Yendon and Grenville Hill—are very alkaline types, chemically related to the Warrenheip series further north. Nepheline appears in the norm of the Clarendon flow, although this mineral was not detected in the slides. Another common feature of this group (Analyses I-IV) is low MgO content, and consequently a low total amount of pyroxenes and olivine. The rocks from Hardie's Hill and Mt. Mercer are less alkaline than the Buninyong group, but much more alkaline than the Ballarat West series.

5. Basalts at Lal Lal Falls

In addition to the Clarke's Hill flow which approached Lal Lal from the north-west down the valley of the ancestor of the present Lal Lal Creek, two thick basalt streams reached the ancient Lal Lal basin from the north. These are exposed in section in the south cliff at Lal Lal falls. The present surface of the top flow near Lal Lal is practically horizontal, but the gentle southerly slope further north shows that the lava probably issued from a vent at Springbank, about two miles north of the township of Wallace, and flowed generally southwards down the valley of the ancestor of the Western Moorabool River, that is, parallel to the adjacent Clarke's Hill flow (Figs. 3, 4, 5).

Near Lal Lal Falls the upper basalt has a maximum thickness of 50 ft. while the lower one shows a face 70 ft. thick. This, however, is not the maximum thickness of the first flow because the gutter of the deep lead filled by this basalt is probably at least 1,000 ft. north-west of the falls and probably at least 50 ft. lower than the bottom of the falls. Thus the total thickness of the two basalt sheets is approximately 170 ft.

Both rocks have very good vertical columnar jointing but the average width of the columns in the top rock, 3 ft., is only half that in the bottom rock, due to slower cooling of the latter. The junction between the two sheets is well defined in the cliff section and presents the following features:

(1) softy clayey decomposed upper portion of the bottom rock;
(2) solid but slightly vesicular base of the top rock;
(3) change of width of columns;
(4) change of lithological character.

At the bottom of the waterfall the basalt rests on decomposed adamellite. A sample of this was examined by Mr. G. Baker, who found a few grains of the minerals tourmaline, zircon, rutile and andalusite, suggesting a possible sedimentary origin. However, it is more likely that the resistant minerals were eroded from the contact aureole above the granitic cupola and remained on its weathered surface.

Petrographical Descriptions

Macroscopically the bottom basalt has dark bluish-grey colour and is very fine-grained and dense. It is very uniform from top to bottom of the sheet. The

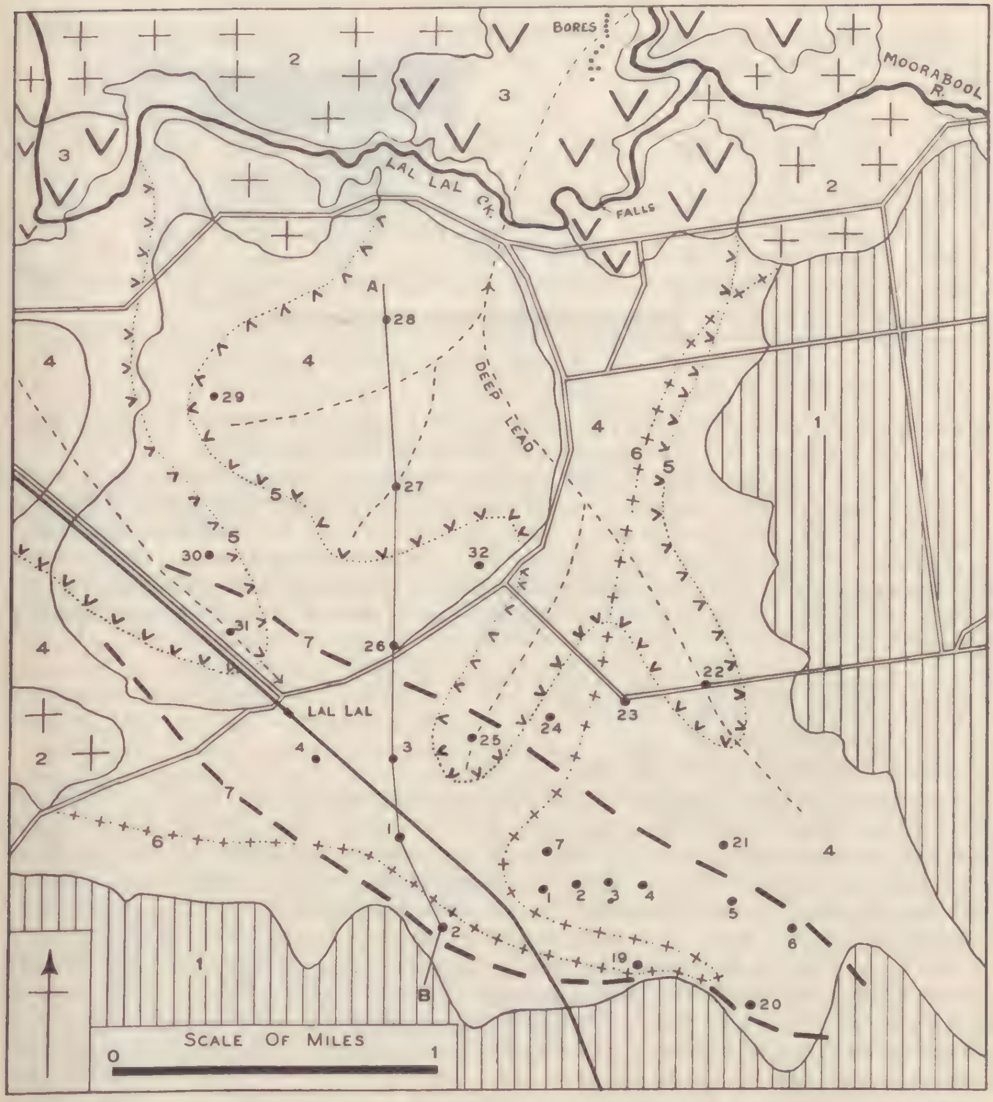


FIG. 4.—Geological Map of Lal Lal, showing bores (numbered dots).

Surface outcrops: 1. Ordovician.
2. Granite.
3. Basalt.
4. Post-Pliocene sands and alluvium.
5. Approx. sub-surface basalt boundaries.
6. Approx. sub-surface granite boundary.
7. Approx. boundary of sub-surface lignite fault basin.

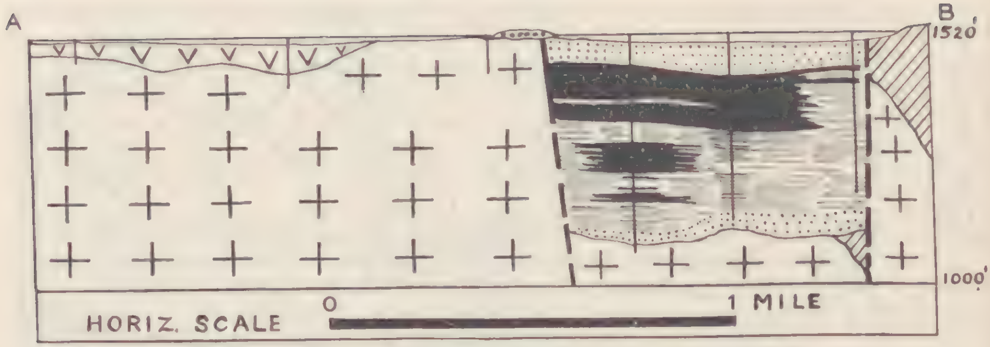


FIG. 5.—Section AB through the lignite basin at Lal Lal.

upper basalt is distinctly coarser grained and has light grey colour. It too is very dense and uniform. No phenocrysts are visible in hand specimens.

Microscopic examination of thin sections shows the bottom rock to be a very felspathic basalt. The plagioclase occurs mainly as irregular grains, but there are some porphyritic laths and prisms. The augite grains are fine and have indefinite boundaries. Fresh olivine is not present, but this mineral is probably represented by numerous small irregular areas of iddingsite. Iron ores are abundant, chiefly cubes of magnetite. The top rock is a good type of olivine basalt, its chief features being:

(1) numerous phenocrysts of fresh olivine $\frac{1}{2}$ to 2 mm. in length;
(2) plagioclase laths $\frac{1}{2}$ to 1 mm.
(3) granular augite;
(4) thin plates of ilmenite up to 1 mm.

Chemical analyses reveal a marked difference between the two basalts. Although both are andesine basalt, the plagioclase is more basic (Ab_{55}) in the bottom rock than in the upper one (Ab_{65}). The Al_2O_3 content is much higher in the first flow and the MgO lower. This is due to greater development of felspar and paucity of olivine. Another notable feature is the exceptionally high percentage of TiO_2 (3·65) in the first flow. The analysis of the top sheet compares quite closely with that of the Clarke's Hill flow, the chief differences being higher MgO and alkalis in the latter, resulting in a small amount of normative nepheline, which is not found in the Lal Lal rock. The sections of these two basalts also are very similar, but the Lal Lal rock has somewhat less olivine, which occurs as smaller phenocrysts. The similarity between the rocks of these two extensive sheets and also the proximity of the vents from which they issued suggest approximate contemporaneity of extrusion from two different points of the same magma cupola.

Differentiation

It cannot be established with certainty that the two basalt sheets at Lal Lal Falls issued from the same vent, but this is probable because the first flow, as shown above, is very thick (120 ft.) here near its extremity and, being confined to the north-south valley of the Moorabool deep lead, could easily have flowed a distance of ten miles from the supposed vent at Springbank. Also, the slightly decomposed nature of the top of this basalt and the absence of sediment between

TABLE 14

	I	II	III		I	II	III
SiO_2 ..	50.12	48.90	50.06	Or ..	9.12	5.56	9.40
Al_2O_3 ..	18.59	13.63	14.73	Ab ..	33.15	31.18	29.47
Fe_2O_3 ..	.77	2.42	1.61	An ..	28.53	17.82	17.23
FeO ..	7.92	8.78	8.49	Ne ..	—	—	2.62
MgO ..	4.06	6.82	7.94	Di ..	1.17	19.19	17.39
CaO ..	6.76	8.77	8.27	Hy ..	14.43	4.41	—
Na_2O ..	3.92	3.68	4.06	Ol ..	2.29	9.53	15.47
K_2O ..	1.54	.94	1.59	Mag ..	1.12	3.50	2.33
TiO_2 ..	3.65	2.62	2.62	Il ..	6.89	4.98	4.98
P_2O_5 ..	.56	.32	.44	Ap ..	1.23	.70	.96
H_2O+ ..	1.52	3.60	.47				
H_2O- ..	.90	.09	.11				
Total ..	100.31	100.57	100.39	Total ..	97.93	96.87	99.84
Plagioclase ..	Ab55	Ab65	Ab65				

I. Andesine basalt, lower flow at Lal Lal Falls.
II. Olivine andesine basalt, upper flow at Lal Lal Falls.
III. Olivine andesine basalt, Gong Gong (Clarke's Hill flow). Analysis I, Table 9.

Analyst: H. Yates.

the two sheets indicate but a short interval between the two extrusions. Assuming, therefore, that they came from the same magma cupola, it is interesting to compare the two rocks as regards mineral composition. The abundance of plagioclase and paucity of olivine in the first (lower) sheet as compared with the upper one points to extensive differentiation in the magma prior to the initial extrusion. Olivine phenocrysts crystallized near the top and then sank to the lower levels of the cupola, where partial resorption took place. This left the upper part of the magma enriched in plagiolclase and augite constituents. The high TiO_2 content of the lower sheet suggests that a second stage in the fractional crystallization prior to extrusion was the concentration of ilmenite molecules in the upper level of the magma. Thus the first extensive lava stream from this vent was impoverished in olivine but rich in plagioclase (basic andesine) and ilmenite constituents, and these latter minerals crystallized after extrusion. The second lava flow contained the abundant olivine phenocrysts from the lower level of the cupola and, furthermore, its plagioclase, of later crystallization, was more acid andesine.

Both flows at Lal Lal Falls have very uniform lithological character from top to bottom and, in view of the negligible variation found in analyses of the individual Ballarat West basalts, a series of analyses at different depths was not undertaken in this case.

6. Basalts and Tuffs at Burrumbeet

In the immediate vicinity of Lake Burrumbeet, 12-15 miles west of Ballarat, the surface basalt is not more than 20 ft. thick, its base being exposed just above the lake level on the north shore. Here, and also on the southern slope of Mt. Callender, bedded volcanic tuff, passing into coarse agglomerate in places, underlies the basalt. On the northern slope of Mt. Callender the same tuff beds were not covered by the final lava flow and now form the surface rock over an area of one square mile, including a prominent low hill one mile east of Mt. Callender. This was a separate vent whose final activity was of the explosive type. The principal

local vents from which the final lava flows issued were Weatherboard Hill, Saddleback Hill and Mt. Callender. Boring investigations by the Department of Mines in 1890 and 1900 established the course of the Ballarat West deep lead between Lakes Burrumbeet and Learmonth and running north-west to the Avoca lead. The bores east of Lake Burrumbeet proved a total thickness of 355 ft. of volcanic materials, while the bores drilled south of Lake Learmonth proved up to 216 ft. of basalts and basaltic clays. No fragmental beds of definite volcanic origin were recorded in these bores, but the thick red clay and "gravelly clay and drift" beneath the basalt at Learmonth may possibly be of pyroclastic origin.

It is clear, therefore, that there was much volcanic activity in this area before the formation of the tuff and agglomerate beds, a conclusion which was arrived at independently by the author as a result of study of the ejected blocks in the agglomerate. These ejected blocks include:

(1) Coarse-grained porphyritic pink biotite granite, traversed in places by veins of aplite and graphic pegmatite.
(2) Very coarse-grained pegmatitic type of granite, consisting of large orthoclase crystals and subordinate quartz and biotite.
(3) Very light grey, fine-grained two-mica granite with muscovite subordinate to biotite. This type is rare.
(4) Numerous friable decomposed volcanic bombs with ellipsoidal shape preserved. It is clear that these were not weathered *in situ* because in most cases they are associated with blocks of hard undecomposed basalt. The conclusion is made that these bombs were exposed for some time on an older land surface following a previous explosive eruption.
(5) At least three different types of basalt distinct from one another and from the final thin surface flows nearby, both as regards lithological character and chemical composition. In view of the slight variation found in thick basalt sheets in other areas these three types of basalt blocks are referred to different lava flows.

It is apparent, therefore, that the Cainozoic volcanoes in the vicinity of Lake Burrumbeet burst through a granitic basement, and at intervals built up at least four distinct basalt sheets and two distinct fragmental deposits. However, without further boring operations the chronological order of those not exposed at the surface cannot be determined. (Figs. 6, 7.)

Description of the Basalts

Included block I (Analysis I, Table 15) is a relatively coarse-grained olivine basalt with doleritic and sub-ophitic texture. It closely resembles the top rock at Ballarat West both in hand specimen and under the microscope. Included block II (Analysis II) is an extremely dense and fine-grained basalt, dark grey-brown in colour. The thin section shows plagioclase laths with good fluidal arrangement, minute grains of augite and cubes of magnetite, and a few small phenocrysts of olivine up to 0·7 mm. in length and partly altered to green serpentine. Block III (Analysis III) is also a fine-grained olivine basalt. The texture is pilotaxitic and fluidal, and there are numerous microphenocrysts of olivine, partly iddingsitized. The hand specimen is dense and bluish-grey in colour.

The surface basalt forming the north cliff of the lake, and also the thin surface flow at Mt. Callender, are fine-grained light grey rocks showing occasional small

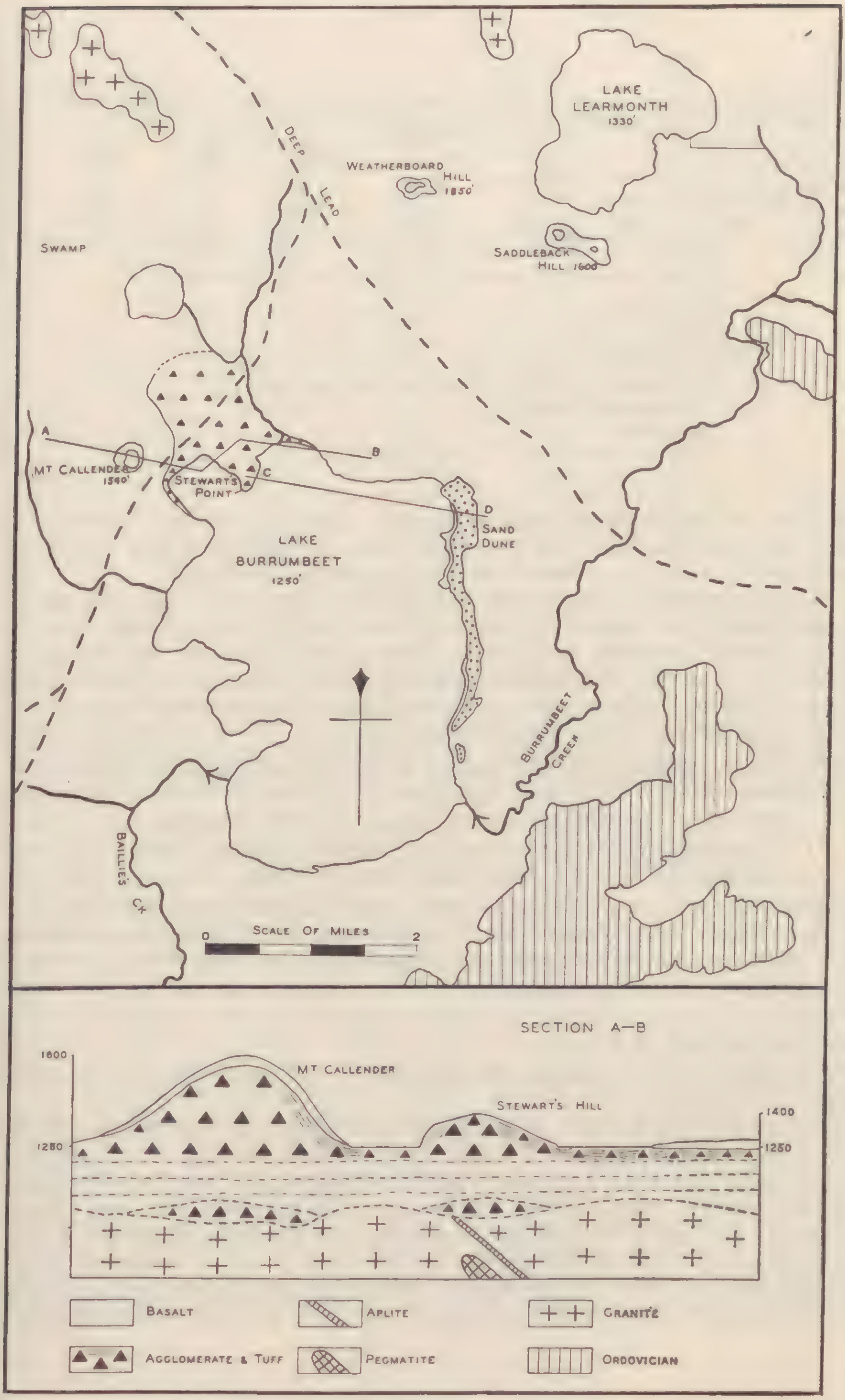


FIG. 6.—Geological map of section of the Burrumbeet area.

FIG. 7.—Sketch section CD across Lake Burrumbeet.

A. Ordovician.
B. Granite.
C. Earlier agglomerate with volcanic bombs.
D, E, F. Earlier basalt flows.
G. Agglomerate and tuff, with older volcanic bombs.
H. Weatherboard Hill basalt.
J. Sand dune.
K. Possible granitic lake bed in places.

phenocrysts of plagioclase in hand specimens. The thin sections resemble that of ejected block II, but there are two generations of plagioclase and augite, giving a few small phenocrysts of these minerals in addition to olivine.

Chemical analyses of the basalts are given in Table 15. They are all olivine andesine basalts, the plagioclase ranging from Ab_{64} to Ab_{52}. Comparison of the analyses reveals variation of the same kind as that found in the basalts of the Warrenheip area, that is, principally an antipathetic variation of the oxides MgO and Al_2O_3. Thus, similar trends of differentiation and contamination in the magma cupola are indicated in this area also, namely:

(1) Early crystallization and sinking of olivine and pyroxene crystals.
(2) Concentration of felspar constituents in the upper levels as a result of convection currents and the sinking of Fe-Mg minerals.
(3) Extraction of felspar constituents from the granitic throat of the volcano, making all the basalts alkaline by contamination.

The effect of these processes is most evident in the composition of the final lava flows from Mt. Callender and Weatherboard Hill. These two analyses, IV and V, are very similar, having low MgO content but high Al_2O_3, consequently both rocks have relatively small amounts of Fe-Mg minerals, but abundant felspars.

Details of the Tuff Beds

T. S. Hart (1901) described the tuffs and their included blocks in considerable detail.

Points of eruption: The very large blocks of granite and basalt set free by wave action are restricted to a stretch about 400 yards long of the rocky beach running north-east from Stuart's Point. This suggests a long narrow north-south vent here, distinct from Stuart's Hill a quarter of a mile to the west. The latter was clearly the source of most of the tuff because the beds dip gently to the east and south away from the hill parallel to its slopes. Mt. Callender was another explosive vent as shown by the easterly dip of the tuffs in the cliff section south-west of Callender Bay. Hart concluded that there were several explosive vents

TABLE 15

	I	II	III	IV	V
SiO_2	50.26	46.69	47.55	49.35	49.34
Al_2O_3	14.80	16.02	15.32	16.10	19.33
Fe_2O_3	4.20	2.02	6.60	4.13	1.85
FeO	7.18	8.93	5.94	7.94	7.92
MgO	7.22	7.58	6.64	4.90	4.28
CaO	8.41	8.31	8.69	7.06	6.94
Na_2O	3.26	3.16	3.36	4.12	4.16
K_2O	1.02	1.30	1.52	1.71	1.51
TiO_2	2.23	3.48	3.01	3.02	3.24
P_2O_5	.37	.42	.57	.34	.32
H_2O+	.72	1.73	.65	.65	.98
H_2O-	.50	.54	.56	.57	.49
Total ..	100.17	100.18	100.41	99.89	100.36
Plagioclase	Ab 56	Ab 52.5	Ab 57.5	Ab 64	Ab 56
Q	.43	—	—	—	—
Or	6.06	7.69	8.99	10.10	8.94
Ab	27.55	26.73	28.40	34.82	35.15
An	22.71	25.64	22.19	20.35	29.56
Di	13.33	10.42	13.49	9.99	2.40
Hy	17.74	1.46	6.57	3.70	2.88
Ol	—	15.53	2.99	7.27	10.48
Mag	6.09	2.93	9.57	5.99	2.68
Il	4.24	6.61	5.72	5.74	6.15
Ap	.81	.92	1.24	.75	.70
Total ..	98.96	97.93	99.16	98.71	98.94

I. Coarse grained andesine basalt block, type I., in the Burrumbeet agglomerate. *Analyst:* H. Yates.
II. Fine grained olivine andesine basalt block, type II., in the Burrumbeet agglomerate. *Analyst:* H. Yates.
III. Fine grained olivine andesine basalt block, type III., in the Burrumbeet agglomerate. *Analyst:* H. Yates.
IV. Olivine andesine basalt, resting on tuff and forming the low cliff, north shore of Lake Burrumbeet. *Analyst:* H. Yates.
V. Olivine andesine basalt, resting on tuff at Mt. Callender. *Analyst:* H. Yates.

in the area, but considered that the main one was in Callender Bay itself, which later subsided. This explanation is not accepted by the present writer.

Structures: The tuffs generally have good lamination, prevalent cross bedding, and local small indented basin structures due to the weight of larger blocks in the fine-grained unconsolidated deposit. These features are similar to those in the tuffs at Lake Purrumbete near Camperdown, described and figured by Hills (1940), and they suggest that most of the tuff at Burrumbeet was formed as "mud flows" from the two main points of eruption, Stuart's Hill and Mt. Callender. Lamination is practically absent in the vicinity of the coarse agglomerate north of Stuart's Point, due, no doubt, to rapid accumulation of the large blocks near this vent. Further north in this cliff section the lamination appears horizontal because the dip here is towards the east. The height of the cliff diminishes to nil at its northern end, due to distance from the main vent, Stuart's Hill, and to erosion by the small creek which enters the lake east of "Stuart's Hotel". To the east of this creek the tuffs pass beneath the thin edge of the final basalt sheet which forms the northern cliff of the lake. The writer has excavated to a depth of several feet in the soft tuff beneath the basalt here. It is finer- and more even-grained than in Stuart's cliff, suggesting that away from the points of eruption the smaller ejected fragments were sorted in lake water more extensive than the present lake.

In addition to the volcanic bombs and blocks of basalt and granite described above, the tuff beds contain a considerable proportion of small angular quartz grains, fragments of basalt and granite, and also occasional grains of fresh felspar and biotite, the whole being set in a brown ferruginous and clayey matrix. The minerals were obviously brought to the surface by volcanic explosion through the basement granite whose surface was in a decomposed condition. Rosiwal measurements from thin sections show that the small quartz grains amount to approximately ten per cent of the tuff in the northern part of Stuart's cliff.

As stated above, no final lava flow issued from the Stuart's Hill vent. However, a small amount of magma was ejected with the fragmental materials and solidified rapidly, forming small grains of tachylite, which is found in the massive tuff on the north-west side of Stuart's Point. The tachylite is black and resinous in hand specimens, but in the thin section it is pale green and isotropic, and shows flow lines in places. The theory of a pyroclastic origin for these fragmental beds at Lake Burrumbeet is supported by definite evidence of vulcanicity in the area, in the form of basalt sheets both above and below, also by the limited number of rock types found as fragments, namely granite, basalt and volcanic bombs, all of which could have been brought up from sub-surface formations, as explained. The possibility of a true sedimentary origin is discounted because of complete absence of fragments rounded by water action.

7. Basalts and Tuff at Smeaton

A great amount of boring was done by the Department of Mines and mining companies in the rich Smeaton alluvial field, to determine the course of the Berry Lead and its tributaries. The writer considered that study of the recorded specimens from a typical bore in this area might yield interesting information concerning the variation of composition in co-magmatic basalt sheets. Bore No. 151, drilled in 1906, was selected because the core specimens preserved are numerous and are numbered in sequence (Table 16). In addition, the depth of each specimen is

Table 16

Details of Berry Consols Extended D.D. Bore No. 151

Rocks pierced	Depth where struck	Thickness	Thickness of basalt sheets	Number of flow	Basalt cores preserved
Clay	0′ 0″	3′ 0″	—	—	—
Basalt gravel	3′ 0″	21′ 0″	—	—	—
Basaltic clay	24′ 0″	12′ 0″	13′ 0″	5	3
Basalt boulders ..	36′ 0″	1′ 0″			
Basalt	37′ 0″	110′ 0″	110′ 0″	4	4
Red clay ..	147′ 0″	8′ 0″		3	9
Basalt	155′ 0″	43′ 6″	51′ 6″		
Decomposed basalt ..	198′ 6″	16′ 6″	48′ 6″	2	11
Basalt	215′ 0″	32′ 0″			
Red and brown clays ..	247′ 0″	36′ 0″			
Vesicular basalt ..	283′ 0″	34′ 0″	82′ 0″	1	13
Hard grey basalt ..	317′ 0″	2′ 0″			
Clays	319′ 0″	7′ 0″	—	—	—
Sandy clay	326′ 0″	14′ 0″	—	—	—
Drift	340′ 0″	8′ 0″	—	—	—
Sandstone bedrock ..	348′ 0″	—	—	—	—

recorded (Table 17). The site of this bore was on the Berry Consols Extended lease, in the vicinity of McRorie's Hill.

Gregory (1903), after detailed examination of bore records to that date, showed that the basalts pierced in the Berry Consols Extended bores probably did not all originate from the same point of eruption, but that separate lava sheets from McRorie's Hill, Woodhouse Hill, Clover Hill and Mt. Moorookyle converged towards a depressed area along this part of the course of the Berry Lead. He described the deep so-called "hydrothermal deposits" in which several of the Mines Department bores were abandoned beneath the basalts as lake beds, but decided against the barrier lake, crater lake and volcanic explosion theories of the origin of the lake. He also concluded that the subsidence probably accompanied the first outbreak of vulcanicity at the McRorie's Hill vent and preceded the lava flows from the other vents in the area.

TABLE 17

Description of Core Specimens Preserved

No. of core Specimen	Depth	No. of flow	No. of Chem. Analysis	Macroscopical Features	Microscopical Features
3	36′ 0″	5	V	Dense, hard brown basalt	Porphyritic olivine andesine basalt with black glassy base
4	63′ 0″	4	IV	Vesicular blue basalt	Coarse ophitic olivine labradorite basalt
9	197′ 0″	3	III	Dense dark brown rock	Acid-andesine iddingsite augite trachy basalt
11	233′ 0″	2	II	Dense, light grey rock with occasional phenocrysts of olivine	Olivine andesine basalt with two generations of olivine. Fine-grained holocrystalline base
13 14	295′ 0″ 307′ 0″	1	I	Vesicular blue rock	Sub-ophitic labradorite basalt

It is difficult to imagine such a localized depression taking place, and in view of the fact that some of the bores were not bottomed at considerable depths in the "hydrothermal deposits" the present writer favours the theory of volcanic explosion along the course of the old river, followed by settling of the fragmental materials and small amounts of lava within the vent as the result of extensive water action. From Gregory's description of the "hydrothermal deposits" it would seem that they were partly sedimentary and partly pyroclastic in origin. Bore No. 151 did not penetrtae these basal deposits, but the core specimen No. 1 described as "basalt gravel" which was met at 3 ft. from the surface and penetrated for 21 ft. resembles basaltic tuff, and indicates that the final volcanic action in this area was also of the explosive type. The basalt core specimens from bore No. 151 are, no doubt, comagmatic, and may be considered as a series except for the possibility

that the different sheets were extruded from neighbouring cupolas of varying compositions. Study of the chemical analyses (Table 18) shows that the rocks are andesine and labradorite basalts. Variation of the important oxides SiO_2 and MgO from flow to flow is considerable, and similar to that found in other series described above. The alkalis, however, vary in a different manner. In most other cases the combined alkalis were either uniformly low or uniformly high, but in the Berry Consols Extended series the total is low in two of the sheets (1, 4) while in the other three it is moderately high.

No certain conclusions can be made from these observations, but it is probable that this type of variation is due to extrusion from several cupolas in which variable convection differentiation had produced different magma compositions. It is also possible that the several vents passed through two different types of basement rocks with resultant variable contamination. The hornblende granodiorite encoun-

Table 18

No. of core specimen	13	11	9	4	3	
Depth	295′	233′	197′	63′	36′	
No. of Flow	1	2	3	4	5	
No. of Analysis	I	II	III	IV	V	VI
SiO_2	50.33	46.45	49.92	48.83	50.80	51.41
Al_2O_3	14.50	14.67	14.21	17.03	14.97	14.78
Fe_2O_3	1.69	1.40	6.59	3.81	1.90	2.20
FeO	8.78	9.37	5.08	6.70	7.13	8.42
MgO	4.18	8.87	5.18	6.97	5.99	6.93
CaO	9.03	7.58	7.96	9.36	9.22	8.30
Na_2O	2.84	3.18	3.74	2.80	3.32	3.70
K_2O	.70	1.52	1.46	.64	1.10	.89
TiO_2	2.30	3.28	2.57	1.86	2.42	1.86
P_2O_5	.32	.63	.49	.29	.34	.30
H_2O-	.88	.69	1.42	1.06	.31	.58
Loss on ignition	5.03	2.35	1.48	.97	2.71	.85
Total	100.58	99.99	100.10	100.32	100.21	100.24
Composition of plagioclase	Ab 51	Ab 60	Ab 65	Ab 45	Ab 57	Ab 61
Q	5.37	—	3.19	.33	.61	—
Or	4.15	8.99	8 64	3.89	6.51	5.27
Ab	24.00	26.82	31.62	23.67	28.06	31.44
An	24.72	21.16	17.67	31.93	22.66	20.97
Ne	—	.05	—	—	—	—
Di	14 93	9.98	14.50	10.13	16.91	14.87
Hy	13.97	—	6.24	18.65	14.34	14.08
Ol	—	20.24	—	—	—	4.78
Mg	2.45	2.03	8.92	5.52	2.76	3.19
Hem	—	—	.43	—	—	—
Il	4.37	6.24	4.89	3.54	4.60	3.54
Ap	.70	1.38	1.07	.63	.75	.65
Total	95.64	96.89	97.17	98.29	97.20	98.79

I. V. Smeaton Basalts. *Analyst:* H. Yates.
VI. Olivine—andesine basalt, Piggbreet. *Analyst:* H. Yates.

tered in the workings was described as a large dyke. It certainly indicates the existence of an unexposed granitic batholith.

8. Differentiation

The marked chemical difference between the basalts of Ballarat West and those of most other areas described calls for petrographical explanation. It is more correct to say that in most areas the basalts are abnormally alkaline and high in Al_2O_3, than that those of Ballarat West are abnormally low in alkalis. Practically without exception these alkaline basalts are rich in olivine, and it is evident that the parent magma was of the olivine basalt type.

One theory to explain the recorded differences of composition in the co-magmatic basalts is that the extrusions in Ballarat West are older than the others, and that in the interval differentiation in the magma reservoir tended to cause concentration of the felspar constituents in the upper levels, with the result that phenocrysts of andesine are common in the later extrusions from Mt. Rowan, Mt. Hollowback, Clarke's Hill, etc., while lime-free anorthoclase appears in the still younger rocks at Mt. Warrenheip. Unfortunately, there is no reliable evidence of the relative ages of the different lavas mentioned, on account of lack of contacts. A second theory is local cupola differentiation as advocated by Edwards (1935). This process may have operated in the majority of centres even before the extrusion of the Ballarat West basalts, so that the latter need not be the first-formed. It is further suggested that the trend of differentiation in the direction stated was assisted by partial solution and assimilation of felspars from the granitic rocks into which the basaltic cupolas and necks rose, thus causing cupola contamination (Fig. 8). In the basalt at Gong Gong quarry and also in some volcanic bombs at Mt. Warrenheip, granitic xenoliths have been found consisting mainly of quartz grains, and this suggests that the felspars had been extracted to some extent.

The effect of such contamination would be to increase the percentages of SiO_2, Al_2O_3 and alkalis in the basaltic magma. The theory is supported by the fact that in the Yendon, Burrumbeet and Warrenheip areas, where distinctly alkaline basalts were extruded, the basement rock is granite. Also, the vents at Clarke's Hill, Green Hill, Buninyong, Millbrook, Gordon and Egerton are situated close to the margin of the outcropping granite, so that granite surrounded the greater part of the necks of these Cainozoic volcanoes. At Smeaton the hornblende granodiorite, met in some of the workings, and described as a large dyke, may have had similar influence on the composition of the lava from certain vents while not affecting others. Though the total alkalis in the Ballarat West basalts are relatively low, they are higher than in normal olivine basalts, and a limited amount of contamination by granitic felspar probably took place as indicated by Fig. 8.

9. Basalts of Other Areas

Despite the considerable time spent in field work, and the number of chemical analyses made, it is felt that much similar work remains to be done. However, many of the bore cores which might be desired have not been preserved. The petrological collection of the Victorian Department of Mines, Melbourne, contains several interesting slides of basalts from the Clunes and Amherst area, but no chemical analyses are available. It would be desirable to have a record of the petrological characters of the many basalt flows from the Divide to Inglewood; also to investigate further, in other areas, the suggested effect of extrusion through

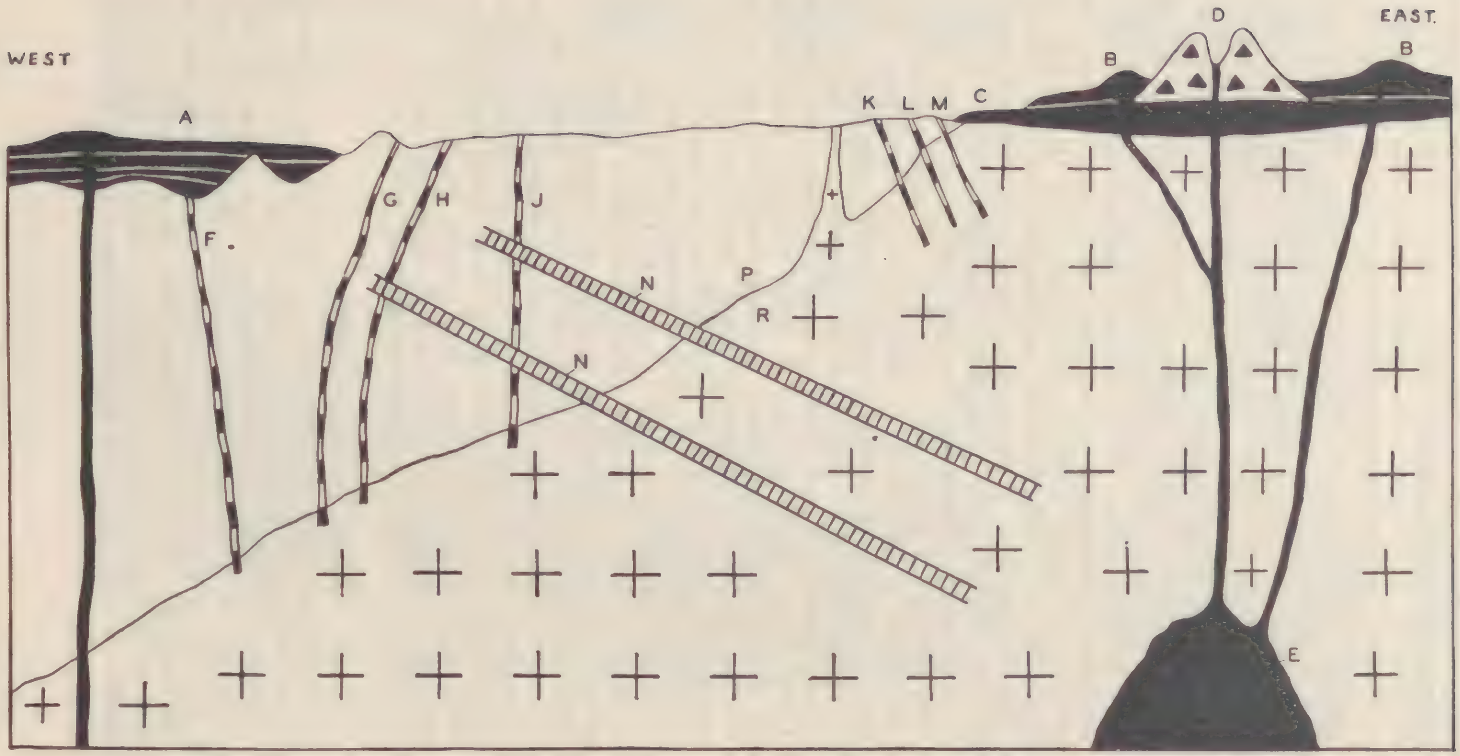


FIG. 8.—Sketch section from Ballarat West to Warrenheip illustrating contamination of basaltic magma by the granitic basement; also the dyke swarm associated with the granite.

A. Ballarat West basalts.
B. Warrenheip basalt.
C. Clarke's Hill basalt.
D. Mount Warrenheip.
E. Basaltic cupola.
F. Quartz-porphyry dyke.
G, H, J. Other acidic dykes.
K, L, M. Aplite dykes.
N. Basic dykes (lamprophyres).
P. Folded Ordovician.
R. Granite.

granitic basements. Some years ago the writer made sections and analyses of two basalt samples taken from the top and bottom of the 50 ft. cliff forming the eastern bank of Smythe's Creek at Piggoreet, in the hope of detecting some variation of composition. Although the section here exposed appears to consist of several thin basalt sheets, because numerous vesicular layers alternate with dense rock, there is but little variation of type from bottom to top, and the section is either a single flow or a series of thin flows from the same vent in rapid succession. Both these slides are olivine andesine basalt, but there is a difference of texture. The bottom layer is ophitic, while the top one has very fine, granular augite.

The two analyses are alomst identical and their average is shown in Table 18, No. VI. The specimens examined are from the final lava flow in this area. The earlier flows, which filled the Grand Trunk lead to the west, are not available for study.

10. Summary and Conclusions

The basalts in the Ballarat district are basic andesine to labradorite varieties, containing olivine. In the rocks of Ballarat West and some of those at Smeaton the combined alkalis have a relatively low total percentage ($3\frac{1}{2}$ to 4), but in most other areas the basalts are more alkaline (total $5\frac{1}{2}$ to $6\frac{1}{2}$) and therefore have a much greater proportion of felspars, while nepheline occasionally appears in the calculated mineral composition. This difference in the basalts is explained by cupola differentiation, involving concentration of the lighter felspar constituents in the upper levels of the cupolas before extrusion. Also this concentration was accentuated in some areas as a result of contamination of the magma by felspar constituents assimilated from granitic basements.

In all cases where a series of basalt sheets rest one upon the other, considerable difference of composition and texture was found from flow to flow. However, in general, practically no variation was found in the same flow at different depths at the same place. It is evident that processes of magmatic differentiation and contamination were active before extrusion and during inter-eruptive periods, but that differentiation was very limited in the lava after extrusion.

Part II.—The Granitic Rocks

The numerous outcrops of granitic rocks within a radius of 25 miles of Ballarat are grouped into three distinct areas, separated by Ordovician slates and sandstones. They are:

(1) The Gong Gong-Lal Lal area.
(2) The Beckworth-Learmonth-Burrumbeet area.
(3) The Mt. Emu-Mt. Bute area.

Other more distant granitic areas occur at Ingliston in the east, Mt. Cole, Lexton and Amphitheatre in the west and north-west, and at Craigie in the north. In the absence of evidence of exact age in most cases these granitic rocks are all provisionally correlated with the Upper Devonian Epoch of intrusion throughout Victoria.

Thus we may picture an extensive Upper Devonian granitic magma underlying the greater part of Victoria, and from this, cupolas of various sizes stoped to different heights before solidifying. Some of these granitic masses were exposed at the surface by erosion before the Permian Period, and most of the others by the Tertiary, because they have been covered by basalt flows. Study of the buried

Tertiary river systems shows that the granites in most cases had been considerably dissected by erosion, and when these valleys were filled with basaltic lava, only isolated granite outcrops remained within the boundaries of the original cupola.

Chemical, mineralogical and textural differences are found in the rocks of different cupolas, and explanation of these involves conjecture as to their underground extent.

In the Ballarat district it was found that the most alkaline rock types occur in the largest cupolas, which also generally rise to the greatest heights; examples are Mt. Cole, Mt. Emu and Mt. Beckworth granites. The Gong Gong, Ingliston and Craigie cupolas are composed of the very common Victorian rock type best described as biotite-adamellite, because they are neither true granites nor true granodiorites. The only true granodiorite found in the district is the biotite-hornblende-granodiorite outcropping as a small stock to the south of Amphitheatre, and it is suggested that this rises from a considerable depth, so that differentiation by convection was limited, and the rock has a composition corresponding to lower levels of the large cupolas, in the upper parts of which gravity and convection caused a concentration of the lighter felspars, orthoclase and microcline.

1. The Gong Gong-Lal Lal Cupola

This forms the basement rock of the Warrenheip plateau. It is now covered to a large extent by basalt, but outcrops at Gong Gong, Warrenheip railway station, Dunnstown, Buninyong East and Lal Lal.

On the Yarrowee Creek, half a mile west of the Gong Gong reservoir, the Ordovician contact rock is spotted micaceous sandstone. The rock type of this cupola is biotite adamellite (Analyses 1, 2, Table 19), and is medium- and even-

Table 19

	1	2	3	4	5	6	7	8	9	10	11
SiO_2 ..	70.22	68.99	71.57	76.96	76.31	71.16	76.22	73.76	74.01	73.98	65.94
Al_2O_3 ..	16.32	15.34	13.58	13.04	12.44	14.06	13.27	15.10	14.05	13.30	15.37
Fe_2O_3 ..	.42	1.00	1.18	.65	.70	2.88	.34	.64	1.80	.61	1.27
FeO ..	1.40	2.56	2.19	.25	.70	2.88	1.06	1.16	1.80	1.40	3.28
MgO ..	.78	1.48	1.07	.08	.22	.89	.13	.04	.45	.71	2.92
CaO ..	2.02	2.16	1.72	.33	.64	1.68	.51	.43	.66	1.56	4.18
Na_2O ..	3.86	3.37	2.79	3.54	2.38	3.16	3.74	3.56	3.10	4.96	3.60
K_2O ..	3.62	3.54	4.36	4.96	6.01	5.70	4.14	4.86	4.72	3.16	1.72
TiO_2 ..	.54	.45	.46	.07	—	.31	.13	.15	.21	.40	.62
P_2O_5 ..	.11	.13	.11	.02	—	.12	nd	nd	.06	.06	.11
							.05	.05			
H_2O+ .	.53	1.03	.69	.44	.42	.34	.25	.57	.58	.44	.84
H_2O-	Nil	.28	.11	.03	.24	.12	Nil	.14	.07	Nil	Nil
MnO ..	—	.11	.09	—	—	—	—	—	—	—	—
Total	99.82	100.44	100.21	100.37	99.36	100.54	99.84	100.17	99.65	100.68	99.85

		Location	*Analyst*
1.	Biotite adamellite	Gong Gong	H. Yates
2.	Idem	—	J. Clark
3.	Biotite adamellite	Ingliston	A. G. Hall
4.	Aplite	Gong Gong	H. Yates
5.	Pegmatite	Lal Lal	F. F. Field
6.	Porphyritic biotite granite	Mt. Beckworth	H. Yates
7.	Aplo-granite	Learmonth	H. Yates
8.	Two-mica granite ejected block	Burrumbeet	H. Yates
9.	Biotite granite	Mt. Bute	H. Yates
10.	Biotite granite	Mt. Cole	H. Yates
11.	Biotite-hornblende-granodiorite	Amphitheatre	H. Yates

grained at Gong Gong, but porphyritic in felspar at Lal Lal. At Warrenheip and Gong Gong the adamellite is traversed by thin north-south veins of aplite which generally dip easterly. The 8 in. vein exposed in the small quarry just south of the Melbourne road on Woodman's Hill passes locally into graphic pegmatite at the margin. At Kirk's reservoir, Gong Gong, the aplite veins are numerous and vary from ½ to 15 in. in thickness. They are quite close together, and most of them are approximately parallel. Is is clear that, after the upper part of the cupola had solidified as adamellite, it developed fairly regular tension gashes while cooling, and along these were intruded streams of the upper part of the remaining magma which had undergone considerable differentiation in the meantime. This explains the more acid and alkaline character of the aplite as compared with the adamellite, and also the paucity of biotite in the former. Along the bounding planes of the aplite and adamellite, and also along joint planes in the latter, grains of molybdenite, chalcopyrite and pyrite occur in places, as at Woodman's Hill. Obviously these were deposited from late magmatic emanations after the intrusion of the aplite.

At Lal Lal, approximately half a mile north-east of the Lal Lal Falls, a large mass of pegmatite occurs within the adamellite, and clearly some depth below the original top of the cupola. Although quarried for felspar many years ago, this rock cannot be traced far on the surface, and is probably an irregular lenticle or pipe. The pegmatite is cream coloured and coarse grained, and consists chiefly of quartz and orthoclase which are micrographically intergrown in places. Large thin plates of biotite occur in parts of the rock.

Baragwanath (*op. cit.*, pp. 54-56) described in some detail the numerous dyke rocks encountered during the mining at Ballarat and thin sections of many of them were made in the laboratories of the Department of Mines, Melbourne. He classified them into an acidic series with strike approximately north-south, and a basic series, mostly east-west. The former include quartz-porphyry, kaolinized felspar-porphyry and felsite, also a dioritic dyke in the Woah Hawp No. 1 mine. The basic series were described as lamprophyres and monchiquites chiefly, also "basaltic dykes" (dolerite) at Brown Hill and Magpie. However, their mineralogical constitution is indefinite in most of the slides, and chemical analyses have not been made. Baragwanath showed that the acidic series of dykes are of the same age as the auriferous quartz reefs but that the basic dykes are younger than the reefs and also younger than the cross-course faults whose fissures they occupy in some cases. It follows that the acidic dykes are of Upper Devonian age and co-magmatic with the adamellite, aplite and pegmatite, but that at least some of the basic dykes are Pliocene or Pleistocene and are magmatically related to the surface basalt sheets. This is probably true of the dolerite and monchiquite dykes, but possibly some or all of the lamprophyres are Upper Devonian and are to be correlated with the lamprophyres at Daylesford, Creswick, Maryborough and Talbot. If so, they complete a typical differentiated dyke swarm in the Ballarat area when studied in conjunction with the aplites, pegmatite, quartz-porphyry and the parent adamellite magma. This relation is illustrated by the section (Fig. 8).

The adamellite at Gong Gong and Lal Lal contains numerous dark xenoliths, generally rounded by partial assimilation. Their grainsize varies from medium and even in some, to fine and porphyritic in others. Thin sections show that these xenoliths are composed entirely of the same minerals as the adamellite itself, namely quartz, plagioclase and biotite. The felspars are quite fresh and the quartz grains show no signs of rounding by water action as would be expected if they had been constituents of sandstones. It is therefore concluded that the xenoliths are cognate

and were freed by stoping of the early solidified upper margin of the cupola. The xenoliths are very numerous near the pegmatite mass at Lal Lal, and in their vicinity the adamellite contains large phenocrysts of poikilitic and crypto-perthitic soda orthoclase (Analysis 1, Table 20).

TABLE 20

	1	2	3	4	5
SiO_2	64.04	65.64	34.42	46.11	.38
Al_2O_3	20.10	19.43	25.84	39.54	—
Fe_2O_3	—	—	—	—	86.94
FeO	—	—	13.07	—	—
MnO	—	—	25.87	—	—
MgO	.05	.04	Nil	—	—
CaO	.26	.10	Nil	—	—
Na_2O	2.10	4.24	nd	—	—
K_2O	12.36	10.04	nd	—	—
TiO_2	—	—	.07	.48	—
P_2O_5	—	—	nd	—	—
H_2O+	.40	.20	nd	14.12	12.68 nd
H_2O-	—	—	nd		
Total ..	99.31	99.69	99.27	100.25	100.00

		Location	*Analyst*
1.	Soda orthoclase phenocrysts in adamellite	Lal Lal	H. Yates
2.	Soda orthoclase	Mt. Beckworth	H. Yates
3.	Spessartite garnet	Learmonth	H. Yates
4.	Kaolin "dyke"	Lal Lal	H. Yates
5.	Limonite	Lal Lal	H. Yates

In the flat areas of the Lal Lal swamps the adamellite near the surface has been decomposed, forming a mixture of kaolin and quartz grains. This clay was used for the manufacture of fire bricks and pottery about the beginning of the century and at the present time it is being produced again from an open-cut mine for use in the manufacture of paper at Ballarat. Other important deposits of kaolin occur as north-south dyke-like masses in the Ordovician rocks of the Mt. Doran ranges east of Lal Lal and also at Mt. Egerton to the north. These kaolin "dykes" are being mined by several different companies and approximately 2,000 tons are being produced annually. No solid rock was found even in the lower levels (150 to 200 ft.), and it is therefore clear that the kaolin was not formed by alteration of igneous rocks by meteoric solutions, but by thorough kaolinization of Upper Devonian felspathic dykes by late acidic emanations from the adamellite magma.

2. THE BURRUMBEET-LEARMONTH-BECKWORTH CUPOLA

Large outcrops of this rock, separated by basaltic plains, form the prominent rocky mountains Mt. Beckworth, Mt. Bolton and Mt. Misery, while the chief of the less prominent outcrops forms a hill one mile north-west of Lake Learmonth. Ejected blocks in the Burrumbeet tuff show that the same rock forms the basement there, and no doubt it was exposed on the early Cainozoic land surface. The characteristic rock type of this cupola, occurring at Mt. Beckworth and Mt. Bolton (Analysis 5, Table 19), is porphyritic biotite granite, the phenocrysts being pink orthoclase with Carlsbad twinning quite common. Many of the blocks at Lake Burrumbeet are of the same type, and some are traversed by thick veins of aplite and graphic pegmatite. It is evident that these blocks, and also those of fine-grained

white two-mica granite, were broken from the upper levels of the cupola, because injected veins and lenses of aplite and pegmatite are numerous in the same granite outcropping at Mt. Beckworth and Learmonth. The occasional blocks of very coarse even-grained pegmatitic granite probably came from lower levels in the cupola where crystallization was uniformly slow.

FIG. 9.—Radial quartz-garnet intergrowth. × 13.

The rock north-west of Learmonth is pink aplo-granite of medium and even grainsize (Analysis 6, Table 19). It consists mainly of quartz and orthoclase, occasionally intergrown, with small quantities of biotite. Lenticular veins of coarse biotite pegmatite are numerous near the top of this outcrop, and at one place only the pegmatite contains crystals of black garnet, while in one of the numerous vughs in the pegmatite an interesting radial graphic intergrowth of garnet and quartz in approximately equal proportions was found (Fig. 9). The garnet is iron-bearing spessartite (Analysis 3, Table 20). No previous reference to such an intergrowth has been found. Andrews (1916) described garnet pipes in granite at Whipstick, N.S.W., and a massive garnet zone in the granite at Yetholme, N.S.W.; some quartz was associated with the garnet, but the two minerals were not intergrown. It is clear that at Learmonth the final pockets of magma were composed chiefly of quartz, and orthoclase molecules, because most of the pegmatite contains no biotite or garnet. A few of them contain large plates of biotite, and one only contains the manganese garnet. In these cases, therefore, the final magma pocket contained concentrations of iron and manganese, and the probable order of crystallization of the pegmatite minerals was: (1) biotite, (2) orthoclase and quartz, (3) garnet and quartz.

In the porphyritic granite on the north-west slope of Mt. Beckworth, near Clunes, a large flat dyke of coarse pegmatite occurs. Although somewhat irregular, it strikes approximately east-west and dips to the south. It is composed mainly of cream-coloured soda orthoclase (Analysis 2, Table 20), with some quartz in the form of large crystals and masses which can be easily separated from the felspar by hand picking. This felspar was tested and used to some extent by Mr. T. Trengrove in the Pottery Department of the School of Mines, Ballarat. It gives a very good quality glaze. Prior to 1914 it was mined by a German syndicate.

3. The Mt. Emu Cupola

The rock outcropping at Mt. Emu north-west of Skipton is a true biotite-granite, cream coloured, and containing abundant orthoclase. This main outcrop stands over 500 ft. above the surrounding basalt plains which separate it from less prominent outcrops to the north, east and west, including a large area in the parishes of Argyle and Mannibadar. Thus the pre-basaltic outcrop of this cupola was about 25 miles N.-S. by 8 miles E.-W. At Mt. Emu the granite contains numerous thin meridional lenticular masses of biotite-pegmatite, also thin veins of aplite and reef quartz. In the vicinity of Flagstaff Hill lookout, west of Linton, the marginal part of the granite has an aplitic texture. The specimen analysed from this cupola was taken from Mt. Bute, three miles south of Linton (Analysis 8, Table 19).

4. The Mt. Cole Cupola

Practically the whole area of this cupola outcrops as a large monadnock north-west of Beaufort, with smaller extensions to the north near Elmhurst, where the principal peak is Mt. Direction, and to the west forming Mt. Buangor, which is separated from the main mass by alluvium in the broad valley of the Wimmera River.

The typical rock, collected from the east and north-east margins of the cupola, is pink biotite granite in which the felspar is chiefly microcline (Analysis 9, Table 19).

5. The Lexton-Amphitheatre Stocks

Two small outcrops of granitic rock occur between Lexton and Amphitheatre, to the east of the Mt. Cole mass, and separated from it and from one another by Ordovician rocks, metamorphosed to a considerable degree. These rocks differ so much from the Mt. Cole granite that they are probably connected with it only at a great depth, descending as nearly vertical stocks. Analysis of the Amphitheatre specimen (No. 10, Table 19) shows it to be granodiorite. The femic minerals are biotite and hornblende, and the rock is medium- and even-grained and light grey in colour. The small stock forming "granite hill" four miles south of Lexton is composed of grey biotite adamellite.

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6

NOTE ON DEVONIAN LIMESTONES BETWEEN THE BLUFF AND BIRD ROCK, WARATAH BAY, VICTORIA

By Curt Teichert

[Read 10 December 1953]

Along the west coast of Waratah Bay between the Bluff and Bird Rock there are almost continuous exposures of limestones which Lindner included in his Bell Point Formation (Lindner 1952). It is possible to distinguish three different limestone members which are all distinct lithologically and palaeontologically and differ from the limestones in the type area of the Bell Point Limestone, near Bell Point and Mushroom Rock.

At the Bluff, now almost entirely removed by quarrying, and for about 100 yards south of it the coastal cliff is formed by hard, thick-bedded, dark limestones which are rich in *Amphipora* and contain in addition specimens of *Favosites* and rugose corals. These rocks strike 30° and dip 45° W. They may be known as the Bluff Member of the Bell Point Limestone and their exposed thickness is about 260 feet. The *Amphipora* biostromes of the Bluff Member are surprisingly similar in appearance to those of the *Amphipora* Limestone of the Desert Basin of Western Australia (Teichert 1949).

The limestone is badly shattered and traversed by innumerable calcite veins. To the north and to the south the outcrops of the Bluff Member are cut off by high-angle thrust faults. Fossils, except *Amphipora*, are difficult to extract from the shattered rock, but one sample (W.B.2) was obtained from the limestone fragments in the crushed rock along the fault forming the southern boundary of the Member. This thrust fault strikes about 17° and dips 50° W and is marked by the development of about 40 feet of black clay, resulting from the crushing of the limestone.

Further south along the coast follow light-grey limestones which are free from *Amphipora* and generally poor in fossils, although they contain some bands of corals and stromatoporoids. These rocks I propose to call the Kiln Member of the Bell Point Formation, because they are well exposed and fossiliferous near the old lime kilns at the former settlement of Waratah. The belt along which the Kiln Member outcrops is divided into three fault blocks by two steep reversed faults, each of which is accompanied by a conspicuous belt of black clayey rock, similar to the one mentioned above. The greatest thickness of the Kiln Member is found in the northernmost of these blocks where the beds dip 65° W and the maximum thickness exposed is 360 feet.

South of the old lime kilns there follows a sandy beach without rock outcrops until the coast swings eastward where it is formed of well-bedded grey limestones and dolomites. These are generally unfossiliferous, but contain lenses of fossiliferous brown limestone. These limestones are lithologically quite distinct from the limestones further north and may be called the Bird Rock Member of the Bell Point Formation, because they continue eastward into the platform on which

Bird Rock stands as an erosion remnant. The thickness of this member has not been determined.

Corals have been collected from all three limestone members as indicated on the map (Fig. 1). Their relative ages cannot be determined from the field evidence, because they are separated from each other by reversed faults.

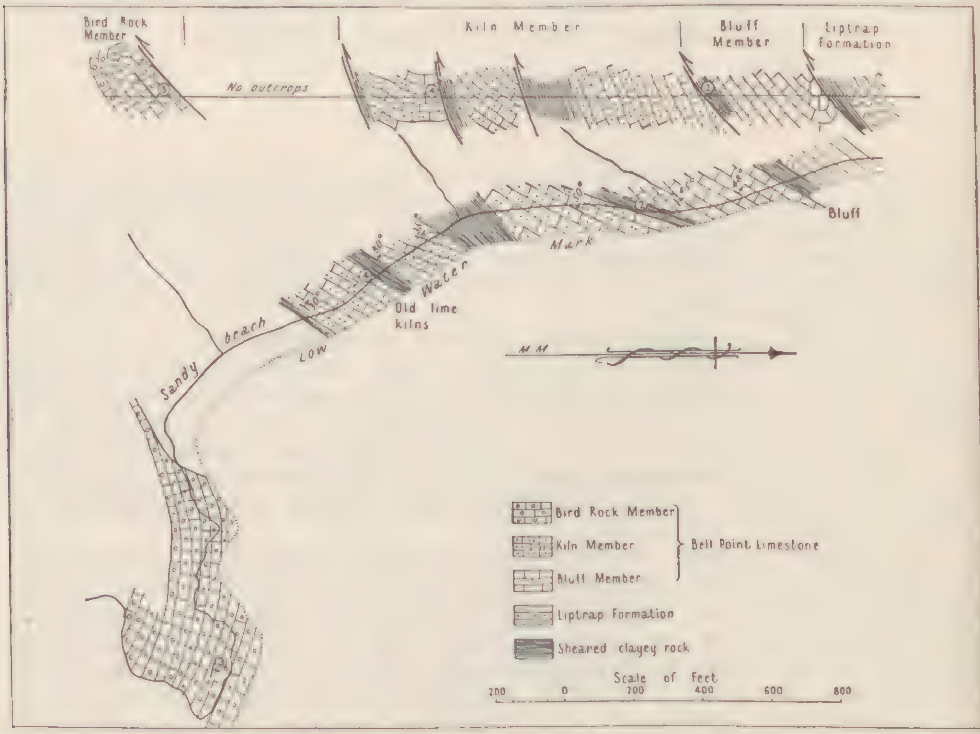

FIG. 1

All three limestone members recognized along the coast between the Bluff and Bird Rock are quite different lithologically from the rocks of the type area of the Bell Point Limestone near Bell Point and Mushroom Rock (see map in Lindner, 1952). The sequence here is much more fossiliferous. In addition to corals there are abundant stromatoporoids, brachiopods, pelecypods, gastropods and ostracodes. These limestones deserve to be distinguished as a separate Member, but more detailed stratigraphical work must be done before this unit can be defined more accurately.

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7

DEVONIAN CORALS FROM WARATAH BAY, VICTORIA

By Dorothy Hill*

[Read 10 December 1953]

Abstract

Rugosa and Tabulata from the disconnected fault slices of Waratah Bay are illustrated, and two new species and one new variety of Rugosa are described. All are Devonian, and all but the new forms are known from other Devonian limestones of Victoria. There is closer similarity to the Lilydale and Loyola faunas, whose precise position in the Devonian is uncertain, than to the Couvinian Buchan fauna.

The material described herein is from the collections of A. W. Lindner and O. P. Singleton, of C. Teichert (Melbourne University) and of the National Museum, Melbourne. The corals are from several localities separated one from another or from early Palaeozoic rocks by faults, the structural relations being described by Lindner (1952) and Teichert (this journal).

Bell Point

The Bell Point fauna has the greatest variety of Rugosa, predominantly members of the family Phillipsastreidae. Of these, *Hexagonaria* aff. *approximans* (Chapman), which occurs also at the base of the Bluff Member of Teichert south of the Bluff, differs slightly from the type specimen from Cooper's Creek, Thomson River, Victoria, and of overseas species is perhaps closest to *H. sedgwicki* (Edwards and Haime) of Ma (1937, Pl. iii, figs. 3a, b) from the ?Middle Devonian of Iowa, U.S.A. *H. stevensi* (Chapman) is known elsewhere only from the Lilydale limestone, regarded as Lower Devonian or doubtfully Middle Devonian. *Disphyllum ?goldfussi* Geinitz is not very different from typical specimens from the Givetian and Frasnian of N.W. Europe and the Givetian of the Kimberleys, Western Australia. *Mictophyllum cresswelli* (Chapman) is known also 200 yards west along the coast from Mushroom Rock (WB6) and near the edge of the Devonian belt west of Mushroom Rock (WB17), as well as from its type locality in the Lilydale limestone. Overseas, *Mictophyllum* is best developed in the upper Devonian of Canada. *M. cresswelli* var. *cylindricum nov.* recalls the species *angulare* Hill from the Couvinian Murrindal Beds of Buchan referred by Hill (1950) to *Disphyllum*. The new variety occurs also near the edge of the Devonian belt west of Mushroom Rock and somewhat below the ostracod limestone south-east of Hughes Jetty. Of the remaining members of the fauna *Tryplasma murrayi* Etheridge is not known elsewhere; this genus is not known in rocks younger than Couvinian. *Favosites goldfussi* d'Orbigny is a common and cosmopolitan Lower and Middle Devonian species, while *F.* aff. *bryani* from south of Bell Point has some of the characters of *F. nitidus* and indicates the Lower or lower Middle Devonian. *Syringopora flaccida* Hill occurs also near the edge of the Devonian Belt west of Mushroom Rock, and in the Cave Limestone (?early Couvinian) fauna of Buchan. The age of the Bell Point fauna is thus Devonian, possibly Couvinian.

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The small collections from WB6 (200 yards west along the coast from Mushroom Rock—*M. cresswelli* and *F.* aff. *bryani*) and WB17 (near edge of Devonian belt, west of Mushroom Rock—*M. cresswelli* and var. *cylindricum*, *Favosites* sp. and *Syringopora flaccida*) clearly are equivalent to at least part of the Bell Point fauna above, as is the fauna WB14 from somewhat below the ostracod limestone south-east of Hughes Jetty with *M. cresswelli* var. *cylindricum*, *M.* sp., *Disphyllum ?goldfussi*, *D.* sp., *Favosites* aff. *bryani* and *Aulopora* cf. *conglomerata* Goldfuss.

Old Kilns

The Kiln fauna from Station G of Teichert on the north side of the Old Kilns (WB4) contains *Lyrielasma ?subcaespitosum* (Chapman) in common with the Bird Rock Fauna, a species known elsewhere from Lilydale and Loyola, *?Pseudamplexus* sp. (a genus fairly characteristic of the Lower Devonian), *F. goldfussi*, *Alveolites ?stamineus* Hill, a species typical of the Couvinian upper Murrindal beds of Buchan, and *Heliolites* sp. This fauna, which occurs in beds mapped by Teichert as the Kiln member of the Bell Point Limestone, is thus Devonian, possibly Lower or Lower Middle Devonian.

Bird Rock

The Bird Rock fauna has *Mictophyllum* (or *Disphyllum*) sp., *Lyrielasma ?subcaespitosum* (in common with the Kiln fauna), *Spongophyllum serratum* Hill, unknown elsewhere but of overseas species closest to *S. sedgwicki* Edwards and Haime from the Middle Devonian (possibly Givetian) of Europe and to *S. ligeriense* Le Maitre (1934) from the French Chalonnes limestone thought to be Lower Couvinian (Assise de Bure), and *Tryplasma wellingtonense* Etheridge known from an unplaced horizon in the Wellington district of N.S.W., and *Tryplasma* sp. This fauna is rich in Tabulata, with *F. goldfussi*, *F. ?ovatiporus* Hill and Jones, ? var. (typical specimens being known from the Lower Devonian Garra beds of N.S.W. and from Loyola in Victoria), *Thamnopora angusta* Lecompte known elsewhere from the Givetian of Belgium and Western Australia, *?T.* sp., *?Striatopora* sp., *Heliolites daintreei* Nich. and Eth. (the common Silurian and Lower Devonian species), *S. flaccida* and *Aulopora* cf. *conglomerata*. The age of the Bird Rock Fauna which occurs in Teichert's Bird Rock member of the Bell Point Limestone is thus Devonian, either late Lower Devonian or early Middle Devonian.

Liptrap Formation

A small fauna P.14 from mudstones with plants towards Cape Liptrap is *Phillipsastrea maculosa* Hill, known also from the ?Lower Couvinian Sulcor Limestone of N.S.W. and the ?Lower Devonian Loyola Limestone of Victoria, *Heliophyllum pinguiseptatum* nov., not dissimilar from *H. halli* of the Onondagan and Hamilton of North America and the Upper Couvinian of Morocco, and *Favosites* aff. *bryani*. This fauna appears to be late Coblenzian or early Couvinian.

Point Grinder

At Point Grinder, *Favosites nitidus* Chapman occurs in beds regarded by Lindner as of the Bell Point Limestone; it is known elsewhere from the Coblenzian Garra beds of N.S.W. and from Cooper's Creek and Deep Creek, Victoria.

The Waratah Bay fauna taken as a whole is thus close to the Lilydale and Loyola faunas, but also has some members of the Buchan faunas. The problem

of the relative ages of these faunas is a very interesting one, which will not yet, apparently, be satisfactorily solved by a study of the corals alone. Some differences may possibly be due to facies or province rather than age.

Description of Species

Order Rugosa

Suborder Streptelasmatina Wedekind, 1927

Superfamily Streptelasmaticae

Family Phillipsastreidae Römer, 1883

Genus **Phillipsastrea** d'Orbigny, 1849; Hill, 1939, p. 236

Prantl (1951) has given a helpful discussion of Devonian thamnastraeoid corals.

Phillipsastrea maculosa Hill, 1942, p. 153. (Pl. VI, figs. 1a, 1b)

Astraeoid or partly thamnastraeoid *Phillipsastrea* with tabularia about 3 mm. wide and 10-15 mm. apart from axis to axis, surrounded by a zone of thickened septa about 2 mm. wide and by a peripheral zone wherein the septa are thin and irregularly carinate; the dissepimentarial floors are arched in the zone of thickened septa, but are declined to the periphery outside this; the tabular floors are horizontal.

One specimen from the mudstones with plants towards Cape Liptrap belongs to this species, previously known from the ?Lower Couvinian Sulcor Limestone of Sulcor Quarry, Tamworth district, N.S.W., and from the ?Lower Devonian Loyola Limestone of Griffiths Quarry, Loyola, Victoria.

Genus **Hexagonaria** Gürich, 1896; Hill, 1953

Hexagonaria stevensi (Chapman). (Pl. VI, figs. 2a, 2b)

Spongophyllum stevensi Chapman, 1925, p. 113.
Prismatophyllum stevensi (Chapman), Hill, 1939, p. 231.

One specimen from Bell Point, Waratah Bay, is referable to this species, known elsewhere only from Mitchell's Quarry, Cave Hill, Lilydale.

Hexagonaria approximans (Chapman). (Pl. VI, figs. 3a, 3b)

Cyathophyllum approximans Chapman, 1914, pl. xlvii.
Prismatophyllum approximans (Chapman); Hill, 1939, p. 234.

Holotype. Nat. Mus. Melb. 1247, Cooper's Creek, Thomson River, Victoria.

Hexagonaria in which the calical profile has a broad humped border and an axial boss; septal trabeculae diverge from near inner edge of dissepimentarium.

Description. The corallites of the cerioid corallum are polygonal, mainly hexagonal, averaging 10 mm. in diameter from angle to angle; in corallites of this size there are 17 or 18 septa to each order, the major extending to an axial boss of tabellae, or to the axis, and the minor to the inner edge of the dissepimentarium, which is 3 to 4 mm. wide; the septa may be thickest near the inner edge of the dissepimentarium, thinning towards both axis and periphery; they may be carinate, with either cross-bar or zig-zag carinae, and there may be an area of divergence in the trabeculae near the inner margin of the dissepimentarium. The dissepiments are small and rather globose, and in parts of many corallites the outermost three

or four series are inclined slightly towards the periphery, while the innermost are inclined steeply towards the axis. The axial tabellae form a boss, and the periaxial are inclined from this towards the dissepimentarium. Both dissepiments and tabellae are thin. The tabularium is 2 to 3 mm. wide.

This species is known at present only from the holotype, so its limits of variation are not defined. Of foreign species it is closest to that illustrated by Ma (1937, pl. iii, figs. 3a, b) as *P. sedgwicki* Edwards and Haime from the ?Middle Devonian of Iowa, U.S.A.

Hexagonaria aff. **approximans** (Chapman). (Pl. VI, figs. 4a, 4b)

Two specimens from Waratah Bay show certain resemblances to *H. approximans*, and are herein named *H.* aff. *approximans*. These are UQ F17115* from Bell Point and MU 2035 from the base of the *Amphipora* Limestone (Bluff Member of Bell Point Limestone) south of Bluff. Of these UQ F17115 differs in having larger corallites, 12 mm. in diagonal diameter, with 20 or 21 septa of each order; also, in some of its septa the carinae may bend along the sides to form a network as seen in transverse section, and the septa tend to be reinforced or replaced peripherally by naotic dissepiments. MU 2035 has still larger corallites, up to 15 mm. in diagonal diameter, though numbers of small, new corallites occur between these large ones; also, some septa may have very notable cross-bar carinae.

Genus **Disphyllum** de Fromentel, 1861

Disphyllum ?goldfussi (Geinitz, 1845). (Pl. VI, figs. 5a, 5b)

One specimen, NM P15405-6, from the '*Palaeosolen*' band of Bell Point may belong to this cosmopolitan, characteristic, Middle Devonian phaceloid species; it is somewhat atypical in having considerable septal dilatation, particularly at the inner edge of the dissepimentarium, and in having the axial edges of the major septa somewhat dilated and stopping short of the axis to form a rather wide axial space.

Disphyllum sp. (Pl. VI, figs. 6, 7)

Several fragments of cylindrical corallites suggesting derivation from phaceloid coralla occur somewhat below the ostracod limestone south-east of Hughes Jetty, Waratah Bay. Whether these are all of one species is doubtful, but all seem referable to *Disphyllum*. Three are figured herein.

One, MU 2025, is slender, 9 mm. in diameter with 28 major and 28 minor septa, the latter extending to the inner edge of the 2 mm. wide dissepimentarium, and the former extending unequally partway to the axis; the septa thin towards the inner edge of the dissepimentarium but are thicker again in the tabularium; the dissepiments are small and globose and the tabellae are in two irregular series, the outer inclined and the inner horizontal. A second, MU 2026, is 10 mm. in diameter, with 26 major and 26 minor septa, most of the latter extending to the inner edge of a dissepimentarium 2 to 4 mm. wide, the former extending unequally into the tabularium partway to the axis. The third, MU 2027, is 12 mm. in diameter and shows greater septal dilatation in the dissepimentarium than either of the others.

*UQ F refers to catalogue numbers of the University of Queensland, MU to those of Melbourne University, NM to those of the National Museum, Melbourne.

Genus **Mictophyllum** Lang and Smith, 1939; Smith, 1945, p. 30

Mictophyllum cresswelli (Chapman), Hill, 1939, p. 246. (Pl. VII, figs. 8a, 8b)

Several large trocho-cylindrical corallites from the Bell Point Limestone of Bell Point, and from near the edge of the Devonian belt west of Mushroom Rock, seem conspecific with those figured Hill, 1939, pl. XIV, figs. 7-9, from the Lilydale Limestone. The Bell Point specimens are weakly compound, large, trochocylindrical of cylindrical offsets appearing by peripheral increase, but none of them show any considerable stereozone like the Lilydale specimen figured Hill, 1939, pl. XIV, figs. 10-11; the diameter of the Bell Point specimens varies, up to 32 mm., and the number of septa seems smaller, 30-33 as against 35 of each order in the Lilydale specimen; also, the minor septa of the Bell Point forms are withdrawn further towards the periphery.

Mictophyllum cresswelli (Chapman) var. **cylindricum** nov.
(Pl. VII, figs. 9a, 9b)

Holotype: MU P4, Bell Point, Waratah Bay.

M. cresswelli with cylindrical corallites up to 18 mm. diameter and with a central down-sinking in the tabular floors.

Description. The corallites are cylindrical (conical at the beginning) and by their apposition suggest that they may be weakly compound, arising by lateral increase. The average diameter of the cylindrical adult portion is 18 mm., with 27 to 30 septa of each order, the major extending unequally and wavily almost to the axis, but typically leaving a space there; the minor are short and may be a little withdrawn from the inner edge of the dissepimentarium, which is 3 to 5 mm. wide; both orders of septa are slightly wavy and somewhat dilated at the periphery and in the dissepimentarium, becoming attenuate axially. The dissepiments are either normal concentric or angular, inosculating; those at the periphery are thickened, the dilatation being in continuity with that of the septa. The tabellae are thin, forming horizontal floors typically with an axial down-sinking in the space free of axial septal ends.

This variety is known so far only from Bell Point and from somewhat below the ostracod limestone south-east of Hughes Jetty.

Mictophyllum sp. (Pl. VII, figs. 10a, 10b)

Two specimens from somewhat below the ostracod limestone south-east of Hughes Jetty, Waratah Bay.

The fragments are cylindrical corallites possibly from phaceloid coralla, with broad low interseptal ridges and narrow septal grooves; diameter 14 mm.; the 26 major and 26 minor septa are dilated, the dilatation decreasing towards the inner edge of the dissepimentarium; the minor septa may be withdrawn somewhat from the inner edge of the dissepimentarium; the major septa may continue unequally to or almost to the axis, with or without waving or curving, and may be more dilated in the tabularium than at the inner edge of the dissepimentarium, while their segments in the tabularium may be discontinuous from their dissepimentarial parts. The dissepiments are small or moderately globose, concentric or inosculating, and when dilated their dilating tissue is continuous with that of the septa. The tabulae are concave.

The relations of these two specimens are uncertain; the inosculating dissepiments and dilated septa suggest *Mictophyllum*, and the thickening of the tabularial

segments of the major septa is like that seen in the Canadian Upper Devonian *M. semidilatum* Smith (1945, p. 31); but I am uncertain whether they form a new species or are referable to *M. cresswelli* var. *cylindricum*. Also, the suggestion of a phaceloid growth form may indicate *Disphyllum* as a more appropriate genus.

Mictophyllum sp. or **Disphyllum** sp. (Pl. VII, fig. 11)

Four fragments of small corallites from the Bird Rock Member of the Bell Point Limestone, north of Bird Rock, Waratah Bay.

The corallites are not more than 11 mm. in diameter at the upper calical edge, and up to 9 mm. at the floor of the calice, which is steep-sided and deep. There are 25 to 27 major septa with an equal number of alternating minor septa; all are dilated to contiguity at the periphery, and the stereozone so formed may be 1·5 mm. wide; in parts of some corallites the dilatation is not complete in the inner half of the minor septa, so that small interseptal dissepiments develop. The major septa are attenuate in the tabularium and considerably withdrawn from the axis, and may be curved. The tabulae appear from the transverse sections (no vertical sections are possible from the material) to be in two series, an outer of inclined angulate plates and an inner of flat plates.

The generic position of these fragments is uncertain; if they are solitary they are probably best referred to *Mictophyllum*; if parts of fasciculate coralla, these would be *Disphyllum*.

Another corallite of 12 mm. diameter at the base of the calice, from Bell Point, has its 1 mm. wide dissepimentarium developed as a stereozone due to the dilatation therein of the 23 major and minor septa; the major septa continue unequally and with curvature to the axis, but are attenuate in the wide tabularium. This fragment could conceivably be the young of *M. cresswelli* or *M. cresswelli* var. *cylindricum*.

Family Zaphrentidae Edwards and Haime, 1850

Genus **Heliophyllum** Hall in Dana, 1846

Heliophyllum pinguiseptatum sp. nov. (Pl. VII, figs. 12a, 12b, 12c)

Holotype. MU 2042, mudstones with plants towards Cape Liptrap, Waratah Bay, Victoria. This is the only specimen known.

Heliophyllum with a wide tabularium in which the long major septa are much dilated.

The corallum is large, apparently solitary, slowly expanding and slightly curved. At a diameter of 35 mm. there are 46 major and 46 minor septa, the latter confined to a narrow dissepimentarium not more than 7 mm. wide; in the dissepimentarium both orders of septa have thick, bulbous yard-arm carinae, from which they attenuate rapidly towards the next inner carina; in vertical section, these carinae appear as thick upwardly and inwardly directed trabeculae; in the tabularium the major septa extend unequally to the axis and are so dilated as to be almost or quite contiguous; a cardinal fossula is visible in the tabularium, closed but expanded inwardly. The dissepiments are small and globose and some series are dilated. The tabulae are sub-horizontal, some dilated, but all of poor development owing to the great thickening of the major septal ends.

This species differs from the North American and Moroccan Couvinian *H. halli* by the persistence of the dilatation of the long major septal ends in the tabularium, by the great width of the latter, and the relatively narrow dissepi-

mentarium. This is the first recorded occurrence of this American and Moroccan genus in Australia. In many coral lineages dilatation of the septa is an early feature.

Family Mucophyllidae Hill, 1940

Genus **Pseudamplexus** Weissermel, 1897; Hill and Jones, 1940

?**Pseudamplexus** sp. (Pl. VII, figs. 13a, 13b)

One fragment of a small cylindro-conical corallum is from the Kiln Member of the Bell Point Limestone from Station G, north side of Old Kilns, Waratah Bay. The size is much smaller than that typical of the genus, and the characteristic stereozone relatively wider, but the occasional blunt spines projecting inwards from the axial septal edges and the flat tabulae are quite characteristic. Occasional interseptal spaces develop. No known Australian species of the genus has such a small diameter. *P. princeps*, the characteristic large Australian species, is typically Lower Devonian.

Suborder Columnariina Soshkina, 1947

Family Acanthophyllidae Hill, 1939

Genus **Lyrielasma** Hill, 1939

Lyrielasma ?subcaespitosum (Chapman, 1925). (Pl. VII, figs. 14a, 14b)

Fragments of erect and tapering corallites with internal structure very similar to that of individual corallites of *L. subcaespitosum* are known from Cave Hill, Lilydale (Hill, 1939, p. 244) and from Waratah Bay at two localities in the Bell Point Limestone, north of Bird Rock in the Bird Rock Member, and north side of Old Kilns, in the Kiln Member. One cannot be sure that these fragments are of solitary corals or of individual from phaceloid coralla; I suspect the latter since one of the fragments (UQ F17101) shows two young offsets in its calice. They differ from individual corallites of *L. subcaespitosum* only in their peripheral stereozone being narrower and more regular, and in their septa inside this stereozone being thinner; but these characters are seen in one individual in the holotype of *L. subcaespitosum* and also characterize most of the individuals in a large phaceloid corallum collected by F. S. Colliver at Griffith's Quarry, Loyola (UQ F12577). Of foreign species they closely resemble *Cyathophyllum elongatum* Le Maitre (1934, pl. V, figs. 10-12) from the Chaudefonds Limestone of France, which is regarded as a Hercynian facies of horizon equivalent to the *Spirifer cultrijugatus* beds, i.e. early Couvinian.

Family Spongophyllidae Dybowski, 1873

Genus **Spongophyllum** Edwards and Haime, 1851; Hill, 1942, p. 254

Spongophyllum serratum sp. nov. (Pl. VIII, figs. 15a, 15b)

Holotype. UQ F17100, north of Bird Rock, Waratah Bay, Victoria, Devonian.

Cerioid *Spongophyllum* with 16 major septa; minor septa only as ridges on the thickened wall, which appear serrated where lonsdaleoid dissepiments are developed.

Description. The corallum is cerioid and the corallites are up to 5 or 6 mm. in diameter, three- to eight-sided; some of the sides may be slightly curved in transverse section. There are 16 major septa in the larger corallites, extending unequally towards the axis, and somewhat wavy, particularly in the tabularium,

where they may be irregularly carinate, the carinae appearing in vertical sections as upwardly projecting thorns; in some corallites one septum may be longer and slightly thicker axially than the others; some or all may be separated from their peripheral bases by one or at most two series of lonsdaleoid dissepiments; at the periphery the septa are thickened to contiguity, forming a narrow stereozone. Minor septa are represented usually only by their bases at the wall, but occasionally segments may be seen within the dissepimentarium. When lonsdaleoid dissepiments develop, the thick wall appears serrated in transverse section because the septal bases project inwards from it; lonsdaleoid dissepiments are thickened only very rarely and slightly. The tabularium is up to 2 mm. wide; the tabulae are complete, slightly sagging and rather distant. Many dissepiments are lonsdaleoid; others may be curved, geniculate or inosculating between neighbouring major septa.

Remarks. Fragments of the holotype only are known. Of the various species of *Spongophyllum* this is perhaps closest to the genotype *S. sedgwicki* from the Middle Devonian of Europe, to *S. ligeriense* Le Maitre (1934) from the French Chalonnes Limestone thought to be of the age of the Assise de Bure, i.e. Lower Couvinian, and to *S. shearsbyi* Etheridge from the Wenlockian of Yass, N.S.W.

Suborder Cystiphyllina Wedekind, 1927

Family Tryplasmatidae Etheridge, 1907

Genus **Tryplasma** Lonsdale, 1845

Tryplasma wellingtonense Etheridge, 1895, p. 160; 1907, p. 89. (Pl. VIII, figs. 16a, 16b)

Solitary, conical at first, then cylindrical, with repeated rejuvenescence sometimes causing slight change in direction of growth, attaining a diameter of 15 mm. or more; septal furrows very faint or absent, the epitheca being marked by rejuvenescence and growth rings only. Root-like processes rare. Septa numerous, acanthine, short, set in continuous lamellar sclerenchyme, forming a stereozone 2 mm. wide; tabulae thin, complete or incomplete.

Five specimens which seem to be referable to this species are from near Bird Rock, in the Bird Rock Member of the Bell Point Limestone; they show the characteristic lack of septal furrows on the epitheca (an unusual feature in solitary *Tryplasma*) but are somewhat smaller than the types from Wellington Caves, N.S.W.

Tryplasma murrayi Etheridge, 1899, p. 32

Tryplasma? murrayi Etheridge, 1907, p. 93.

Type Material. Geol. Surv. Vic., Waratah Bay, near Wilson's Promontory, S.E. Victoria.

Diagnosis. Corallum probably phaceloid but manner of increase unknown. Corallites long, cylindrical, straight and in bundles; diameter 11 mm.; interseptal ridges flat; stereozone narrow; acanthine septa equal, short, about 50; tabulae complete or incomplete.

I have seen only one specimen, NM P15412, from Bell Point, not *in situ*; this does not permit me to add anything to Etheridge's description.

Tryplasma sp.

Three small, slenderly conical coralla with smooth epitheca (diameter up to 5 mm. at floor of calice), a few root-like processes, complete tabulae and short

acanthine septa may be young specimens of *T. wellingtonense*, but do not seem to expand in diameter sufficiently rapidly for that species, and are referred to herein as *Tryplasma* sp. They are known from the Bird Rock Member of the Bell Point Limestone near Bird Rock.

Order Tabulata

Family Favositidae Dana, 1846

Subfamily Favositinae Dana, 1846

Genus **Favosites** Lamarck, 1816

Favosites goldfussi d'Orbigny, 1850; Jones, 1936, p. 19. (Pl. VIII, figs. 19, 20)

A tabular colony from the Bird Rock Member of the Bell Point Limestone from Bird Rock shows the characteristic ragged corallite wall, with mural pores not sharply bounded and sometimes merging with irregular holey imperfections. Small pieces of colonies are known from the Kiln Member, on the north side of the Old Kilns. A specimen with corallites 2 mm. in diameter comes from Bell Point (GSV 20083).

Favosites nitidus Chapman; Hill and Jones, 1940, p. 198. (Pl. IX, figs. 25a, 25b)

A typical specimen, UQ F17109, was collected from Point Grinder.

Favosites ?ovatiporus Hill and Jones, 1940 var. (Pl. VIII, figs. 21, 22)

Four specimens from the Bird Rock Member of the Bell Point Limestone from Bird Rock bear notable resemblances to *F. ovatiporus* but differ in possessing septal spines; one differs in having slighlty larger corallites, and two in having slightly smaller corallites.

P.15424 Nat. Mus., Melbourne, has, like the type, polyhedric corallites 0·75 to 1·5 mm. in diameter, the majority being 1 mm., slightly thickened; also, the tabulae are distant and the oval mural pores are in one series in the middles of the faces. The pores are however rather smaller than is typical, their centres about 1 mm. apart; also, septal spines occur, thorn-like mostly, thickening at the base and directed slightly upwards from the horizontal, about eight around a corallite, a few being base to base in neighbouring corallites. In MU 2036 and UQ F17088 the corallites are smaller, 0·5 to 0·1, average 0·75 mm. In UQ F17095 the corallites are larger, up to 2 mm. in diameter, and the septal spines are shorter and quite horizontal, not base to base in neighbouring corallites. The oval pores in this specimen are slightly larger than those in the others.

A tentative determination only is made, in view of the small number of specimens. *F. ovatiporus* is known elsewhere in the Lower Devonian Garra Beds of N.S.W. and the ?Lower Devonian Loyola Limestones of Victoria.

Favosites aff. **bryani** Jones, 1937; Hill, 1950, p. 150. (Pl. IX, figs. 23, 24)

F. bryani typically has thick-walled (0·125 mm.) polygonal corallites 1 mm. in diameter, with a single median row of round mural pores (0·25 mm. in diameter and 0·5 mm. between centres) in each face and with the fibres of the septal trabeculae at the upper and sometimes the lower rims of pores grouped in long sharp-edged eaves-like squamulae; discrete septal spines also occur at the sides of the mural pores. Tabulae are numerous, up to 18 in 5 mm., usually complete and horizontal, sometimes inclined or sagging and suspended from squamulae.

MU 2040, from 200 yards along the coast from Mushroom Rock, differs from the type of *F. bryani* in having slightly larger corallites, 1 to 1·5 or even 1·75 mm. in diameter, with more incomplete tabulae, and the centres of the mural pores 0·8 mm. apart. UQ F17106, from south of Bell Point, differs in having smaller corallites, average 0·8 mm. and more distant, complete tabulae, thus approaching *F. nitidus*.

UQ F17111, from the mudstones with plants towards Cape Liptrap, differs in having corallites with rounded lumina due to thickening of the walls at the angles and in having squamulae horizontal rather than upwardly projecting; such a direction is characteristic of *F. pluteus* Hill from the Couvinian limestones of Buchan, but in the Liptrap specimen the squamulae are dilated at their bases like those of *F. bryani*. This individual is thus in some ways intermediate between *F. bryani* and *F. pluteus*.

Three irregular globular small colonies from somewhat below the ostracod limestone south-west of Hughes Jetty, Waratah Bay, have corallites of average diameter 0·6, 0·75 and 0·8 mm. respectively; the mural pores are very large in the corallum with smallest corallites, being up to 4 mm. diameter, and occupying the whole width of a face. These are doubtfully grouped with *F. bryani*.

Genus **Thamnopora** Steininger, 1831; Hill, 1953

Thamnopora angusta Lecompte, 1939, p. 115. (Pl. IX, figs. 26a, 26b, 26c)

Cylindrical stems 8 to 10 mm., simple or forked, with polygonal calices opening perpendicularly or with slight obliquity 0·75 to 1 mm. in diameter; corallites widening very little in their course with walls moderately thick throughout; pores 0·2 mm. in diameter.

In the Bird Rock Member with *Amphipora* of the Bell Point Limestone north and west of Bird Rock many cylindrical fragments of stems occur which differ from the Belgian Givetian types only in the slightly greater thickness of the walls in the periphery of the branch relative to their thickness in the axial parts. *T. angusta* is known from the Givetian *Amphipora* Limestone near the base of the Pillara Limestone in the West Kimberleys, W.A.

?**Thamnopora** sp. (Pl. IX, figs. 27a, 27b, 27c)

One fragment of a cylindrical branch 7-8 mm. in diameter collected from the Bird Rock Member of the Bell Point Limestone west of Bird Rock has calices opening somwhat obliquely or perpendicularly less than 0·5 mm. in diameter; the calices of some are elongate, others open into any one or sometimes two of their neighbours by a wide canal possibly the work of a boring organism, so that the double calices simulate one very elongate calice and a vermiculate appearance is given to the surface of the branch. The corallites in the axial parts are polygonal or partly rounded in section; the walls are thick throughout, so much so that the corallite may be filled entirely except for the ?bored canals. Tabulae are not seen, nor septal spines, but mural pores are frequent.

The relations of this specimen are uncertain; the corallites are too small for reference to *T. angusta*; possibly it is related to *Scoliopora* rather than to *Thamnopora*, but more material is necessary.

Genus **Striatopora** Hall, 1851; Hill, 1953

?Striatopora sp. (Pl. IX, figs. 28a, 28b)

Two fragments from the Bird Rock Member of the Bell Point Limestone are doubtfully included in *Striatopora*.

The branches are tapering, circular in section, up to 15 mm. observed. The corallites are up to 2 mm. in diameter, and polygonal, with walls 0·25 to 0·3 mm. thick in the axial parts of the branch. The corallites curve to open approximately perpendicularly to the surface of the branch, the steepest part of the curve being about 2 mm. from the surface. In a peripheral zone 2 mm. wide the walls are so thickened as to fill the corallite, and just inside this the tabulae may be thickened. The minute structure of the thickened walls is unfortunately obscured, but it may well have been striatoporoid. The tabulae are distant axially, but become closer peripherally. Mural pores are frequent, circular, 5 in a space of 3 mm., and 0·13 mm. wide.

Subfamily ALVEOLITINAE Duncan, 1873

Genus **Alveolites** Lamarck, 1801

Alveolites ?stamineus Hill, 1950, p. 144. (Pl. IX, fig. 29)

A very small fragment of *Alveolites* from the Kiln Member of the Bell Point Limestone of Station G, north side of Old Kilns, Waratah Bay, is doubtfully referred to *A. stamineus*. The corallites are smaller (average height 0·31 mm.) and apparently, from the oblique section available, less semilunar and more flattened in section than is typical; but not so much so as in *A. lemniscus* Smith, a European species from the *Spirifer cultrijugatus* beds of Fourmies. Mural pores are present at the angles; tabulae are rare and septal spines are not observed.

Family HELIOLITIDAE Lindström, 1873

Genus **Heliolites** Dana, 1846

Heliolites daintreei Nicholson and Etheridge, 1879; Jones and Hill, 1940, p. 199. (Pl. IX, fig. 30)

Small flattened globular or flattened hemi-spherical colonies less than 30 mm. in diameter occur in the Bird Rock Member of the Bell Point Formation north of Bird Rock. Two of these are of the fourth group described by Jones and Hill characteristic of Silurian and early Devonian faunas; another is without trace of septa and has walls of tabularia and tubuli considerably thickened.

Family AULOPORIDAE Edwards and Haime, 1851; Lecompte, 1939, p. 175

Subfamily AULOPORINAE Edwards and Haime

Genus **Aulopora** Goldfuss, Lecompte, 1939, p. 175

Aulopora cf. **conglomerata** Goldfuss, 1829; Hill, 1950, p. 156

One specimen, from the Bird Rock Member of the Bell Point Formation, west of Bird Rock, differs from those Buchan specimens described by Hill (1950, p. 156) in having some corallites longer than 3 mm. without an offset being produced, at least on the side of the branch visible on the weathered surface. Another, from somewhat below the ostracod limestone south-east of Hughes Jetty, encrusting *Mictophyllum*, is more typical.

Subfamily Syringoporinae de Fromentel, 1861

Genus **Syringopora** Goldfuss, 1826

Syringopora flaccida Hill, 1950, p. 157. (Pl. IX, figs. 31a, 31b)

Two specimens from the Bird Rock Member of the Bell Point Limestone north of Bird Rock appear to belong to this species though many corallites have their stereozone thicker than 0·2 mm. the characteristic thickness in the Cave Limestone, Buchan.

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Explanation of Plates

Plate VI

Fig. 1.—*Phillipsastrea maculosa* Hill. UQ F17110, mudstones with plants towards C. Liptrap. Thin sections × 2, *a* transverse, *b* vertical.

Fig. 2.—*Hexagonaria stevensi* (Chapman). UQ F17117, Bell Pt., thin sections × 2, *a* transverse, *b* vertical.

Fig. 3.—*Hexagonaria approximans* (Chapman). Holotype, Nat. Mus. Melb. 1247, Cooper's Ck., Thomson R., Vic., Devonian; thin sections × 1·8, *a* transverse, *b* vertical.

Fig. 4.—*Hexagonaria* aff. *approximans* (Chapman). UQ F17115, Bell Pt., thin sections × 2, *a* transverse, *b* vertical.

Fig. 5.—*Disphyllum ?goldfussi* (Geinitz). Nat. Mus. Melb. P15405-6, *Palaeosolen* band of Bell Pt., thin sections × 1·8, *a* transverse, *b* vertical.

Fig. 6.—*Disphyllum* sp. MU 2025, somewhat below the ostracod limestone south-east of Hughes Jetty, thin sections × 1·8, *a* transverse, *b* vertical.

Fig 7.—*Disphyllum* sp. MU 2027, somewhat below the ostracod limestone south-east of Hughes Jetty, thin transverse section × 1·8.

Plate VII

Fig. 8.—*Mictophyllum cresswelli* (Chapman). UQ F17134, near edge of Devonian belt, west of Mushroom Rock, thin sections × 1.8, *a* transverse, *b* vertical.

Fig. 9.—*Mictophyllum cresswelli* var. *cylindricum* nov. Holotype, MU P4, Bell Pt., thin sections × 2, *a* transverse, *b* vertical.

Fig. 10.—*Mictophyllum* sp. MU 2023, somewhat below ostracod limestone south-east of Hughes Jetty, thin sections × 1.8, *a* transverse, *b* vertical.

Fig. 11.—*Mictophyllum* sp. or *Disphyllum* sp. UQ F17099, north of Bird Rock, thin transverse section × 1.8.

Fig. 12.—*Heliophyllum pinguiseptatum* sp. nov. Holotype, MU 2042, mudstones with plants towards C. Liptrap, thin sections × 2, *a* and *c* transverse, *b* vertical.

Fig. 13.—*?Pseudamplexus* sp. MU 2031, Station G, north side of Old Kilns, Kiln Member, Bell Pt. Limestone, thin sections × 1.8, *a* transverse, *b* vertical.

Fig. 14.—*Lyrielasma ?subcaespitosum* (Chapman). UQ F17101, north of Bird Rock, thin sections × 1.8, *a* transverse, *b* vertical.

Plate VIII

Fig. 15.—*Spongophyllum serratum* sp. nov. Holotype, UQ F17100, north of Bird Rock, thin sections × 1.8, *a* transverse, *b* vertical.

Fig. 16.—*Tryplasma wellingtonense* Etheridge, UQ F17090, north of Bird Rock, thin sections × 1·8, *a* transverse, *b* vertical.

Fig. 17.—Rugosa gen. et. sp. indet., Nat. Hist. Melb., P15407, *Palaeosolen* band, Bell Pt., thin sections × 1·8, *a* transverse, *b* vertical.

Fig. 18.—Rugosa gen. et. sp. indet., Nat. Mus. Melb., P18411, '*Euomphalus*' region, Bell Pt., thin transverse section × 1·8.

Fig. 19.—*Favosites goldfussi* d'Orbigny. UQ F17094, north of Bird Rock, thin sections × 1·8, *a* transverse, *b* vertical.

Fig. 20.—*F. goldfussi.* MU 2032, Station G, north side of old Kilns, Kiln member, Bell Pt. Limestone, thin sections × 1·8, *a* transverse, *b* vertical.

Fig. 21.—*Favosites ?ovatiporus* Hill and Jones, ?var. MU 2036, west of Bird Rock, thin sections × 1·8, *a* transverse, *b* vertical.

Fig. 22.—*F. ?ovatiporus* ?var. UQ F17095, north of Bird Rock, thin sections × 1·8, *a* transverse, *b* vertical.

Plate IX

Fig. 23.—*Favosites* aff. *bryani* Jones. MU 2040, 200 yards along coast from Mushroom Rock, thin sections × 1·8, *a* transverse, *b* vertical.

Fig. 24.—*F.* aff. *bryani.* MU 2028, somewhat below ostracod limestone, south-east of Hughes Jetty, thin section × 1·8.

Fig. 25.—*Favosites nitidus* Chapman. UQ F17109, Pt. Grinder, thin sections × 1·8, *a* transverse, *b* vertical.

Fig. 26.—*Thamnopora angusta* Lecompte. UQ F17102, north of Bird Rock, thin sections × 1·8, *a* transverse, *b* tangential, *c* vertical.

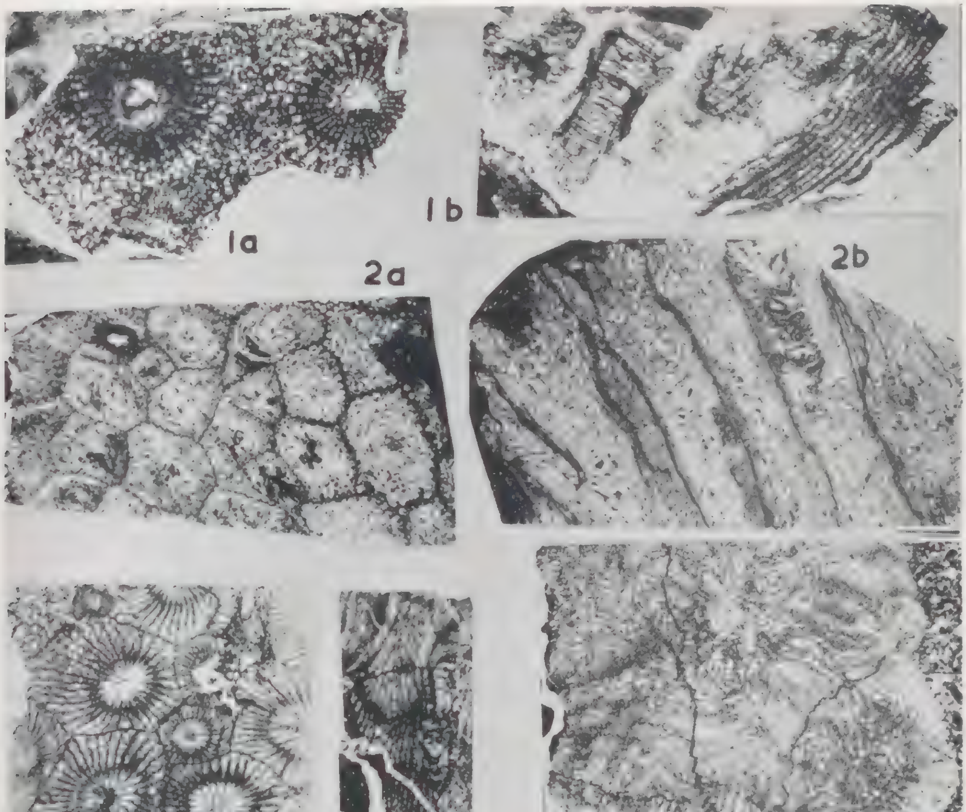
Fig. 27.—?*Thamnopora* sp. MU 2037, west of Bird Rock, thin sections × 1·8, *a* transverse, *b* tangential, *c* vertical.

Fig. 28.—?*Striatopora* sp. MU 2038, west of Bird Rock, thin sections × 1·8, *a* transverse, *b* vertical.

Fig. 29.—*Alveolites ?stamineus* Hill. MU 2033, Station G, north side of Old Kilns, Kiln Member, Bell Pt. Limestone, thin section × 1·8.

Fig. 30.—*Heliolites daintreei* Nicholson and Etheridge. UQ F17086, north of Bird Rock, thin transverse section × 1·8.

Fig. 31.—*Syringopora flaccida* Hill. UQ F17113, Bell Pt., thin sections × 1·8, *a* transverse and oblique, *b* vertical.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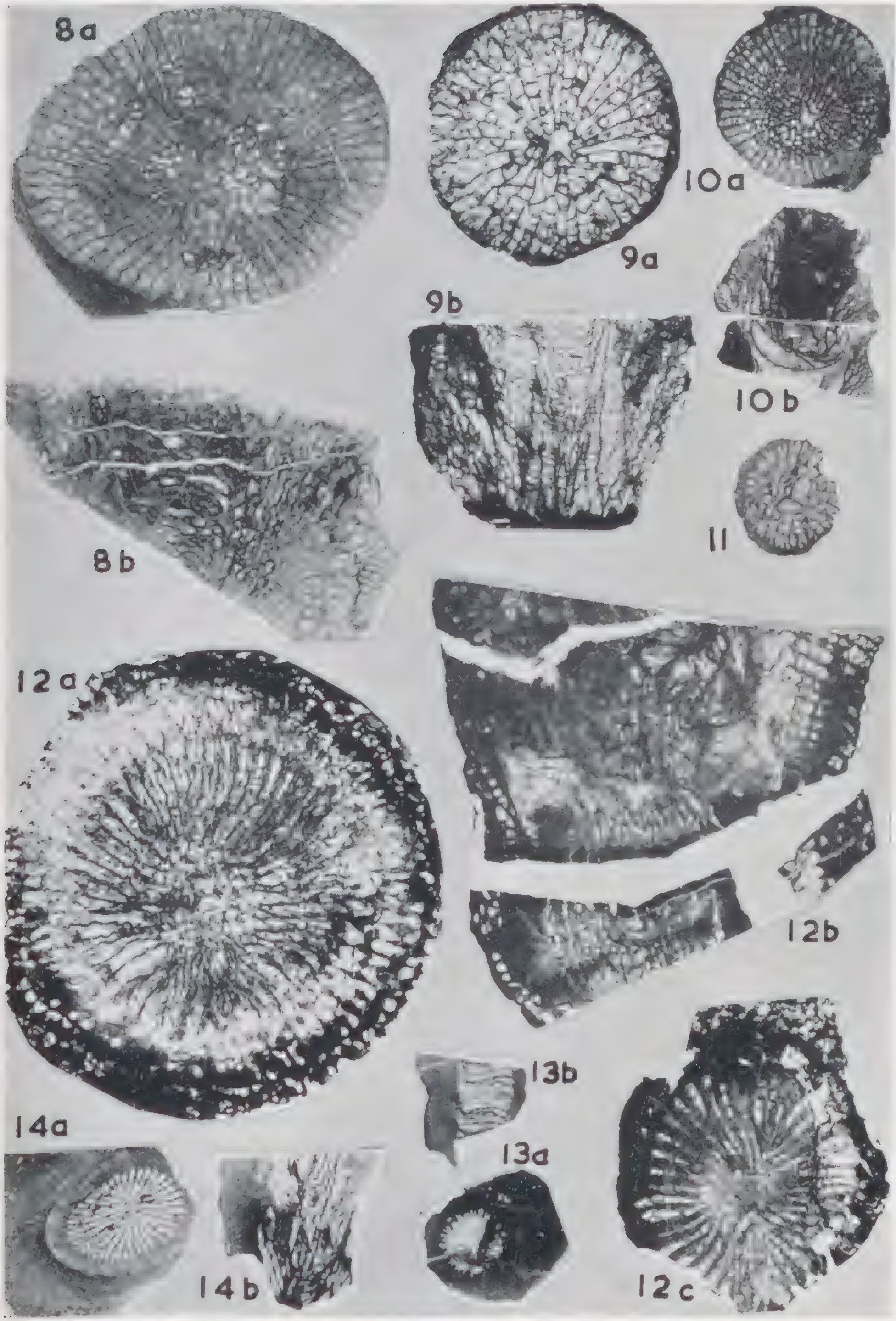
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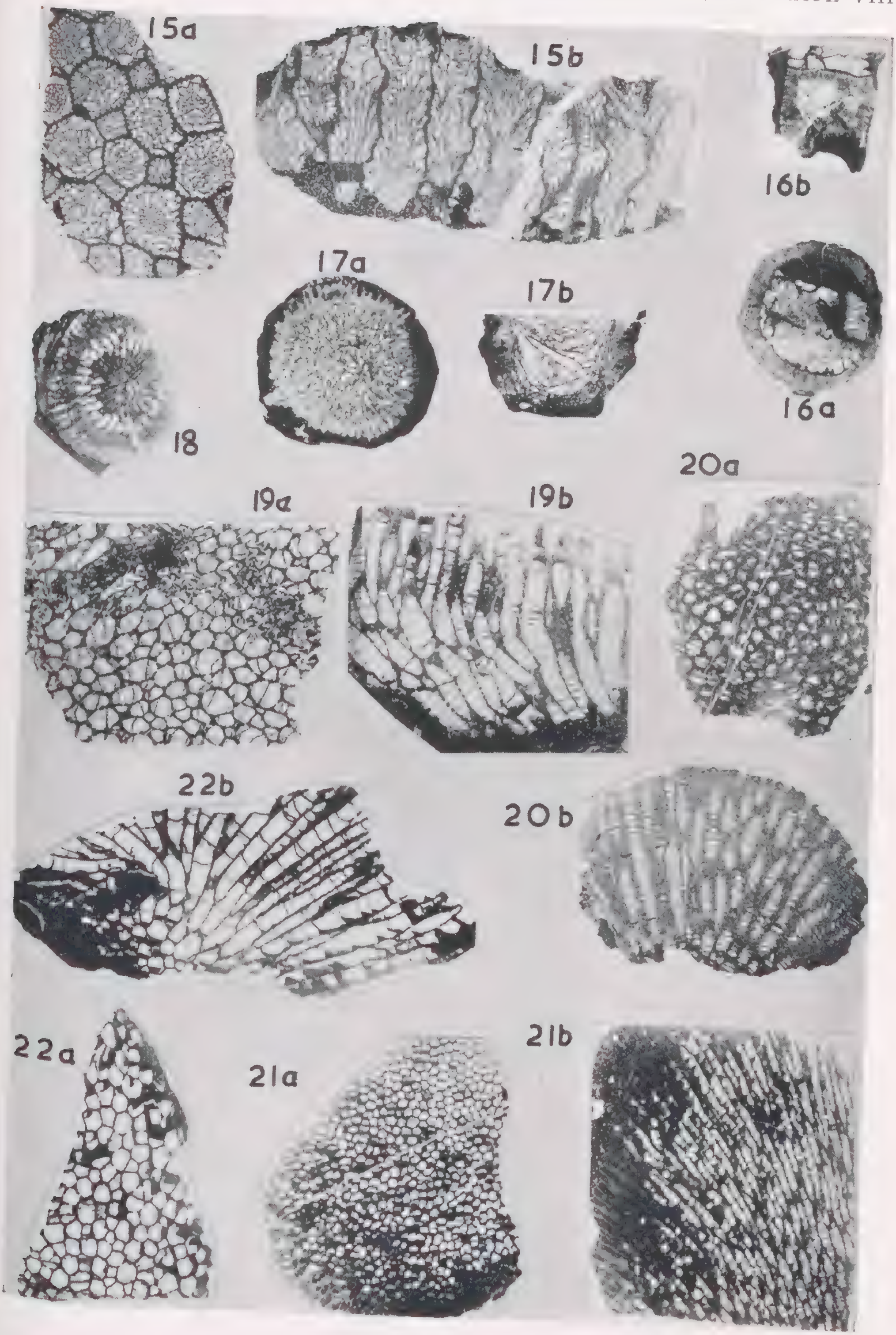
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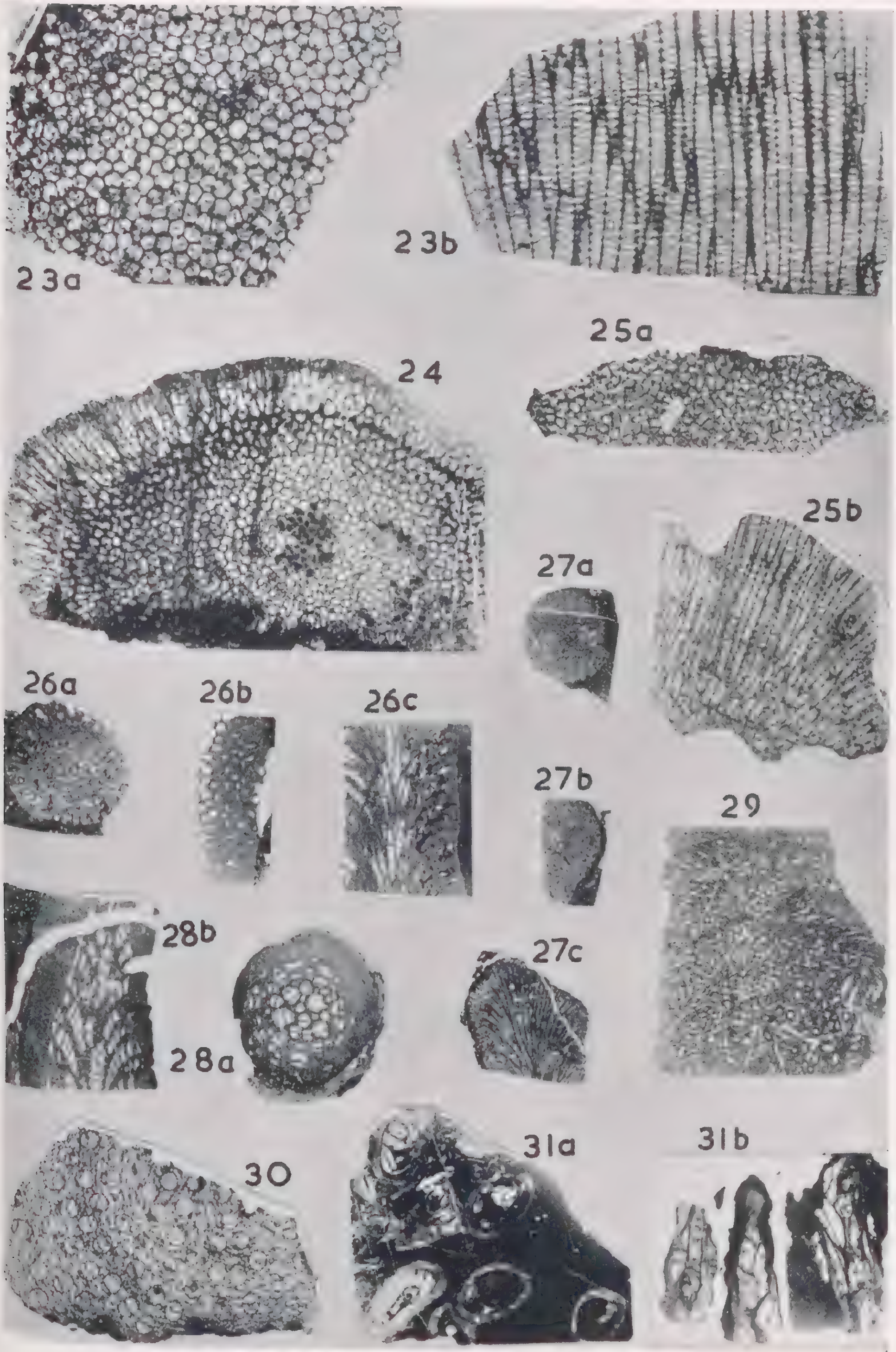
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8

A PALYNOLOGICAL EXAMINATION OF NO. 1 BORE, BIRREGURRA, VICTORIA

By Isabel C. Cookson, D.Sc.

[Read 10 December 1953]

Summary

Three microfloras have been recognized in No. 1 Government Bore, Parish of Birregurra, Victoria, and each has been tentatively related to microfloras of other deposits.

Introduction

Plant remains are generally regarded as less satisfactory determinants of exact geological age than are marine fossils. Many genera have a long time-range and one that may vary from one country to another, as can be shown, for example, by a comparison between the Cretaceous and Tertiary microfloras of New Zealand and Australia. Recently Suggate and Couper (1952) and Couper (1953) have shown that in New Zealand the sporomorph *Dacrydiumites mawsonii* Cookson and pollen grains of *Nothofagus*, which in Australia seem to make their first appearance in Older Tertiary deposits, occur in the Paparoa beds which are believed to be of Lower Cretaceous age. Furthermore, neither the pollen of *Nothofagus* nor that of any other dicotyledonous species has, as yet, been recognized in residues of Australian Late Mesozoic deposits, although they have been looked for carefully in the Styx River Series of Queensland (probably Lower Cretaceous, Walkom 1919), in which dicotyledonous leaves occur, and the Styx and Burrum Coal Measures (de Jersey, 1951). On the other hand assemblages of plant remains, both macroscopic and microscopic, have often proved extremely useful in correlations between more closely situated strata (Thiergart, 1949).

Most of the palynological work on Australian Tertiary deposits has been carried out on isolated samples of individual and often unrelated beds rather than on a continuous vertical section, and has been mainly concerned with the botanical identification of the various pollen and spore types present in them. Core samples from near the Tertiary-Mesozoic junction at Comaum, South Australia, have been analysed and two microfloras identified (Cookson, 1953), but nothing of a similar nature has been recorded from Victoria before.

This position has now been rectified to some extent by an examination of sampels from No. 1 Government Bore Core, Parish of Birregurra, in south-western Victoria, kindly made available by Dr. D. E. Thomas, Chief Geologist, Mines Department of Victoria. This examination shows that definite changes in the pollen and spore content occur at three levels and indicates that some of these are sufficiently significant to provide a basis for comparison with microspore assemblages from other deposits in Victoria.

The portions of the Birregurra Bore studied came from the following levels: 444-515 feet, 760-960 feet, 1006-1020 feet, and 1076-1090 feet respectively. The break in the deeper parts of the bore is partly accounted for by 33 feet of basalt encountered at 1022 feet. The Mesozoic bedrock was struck at 1063 feet.

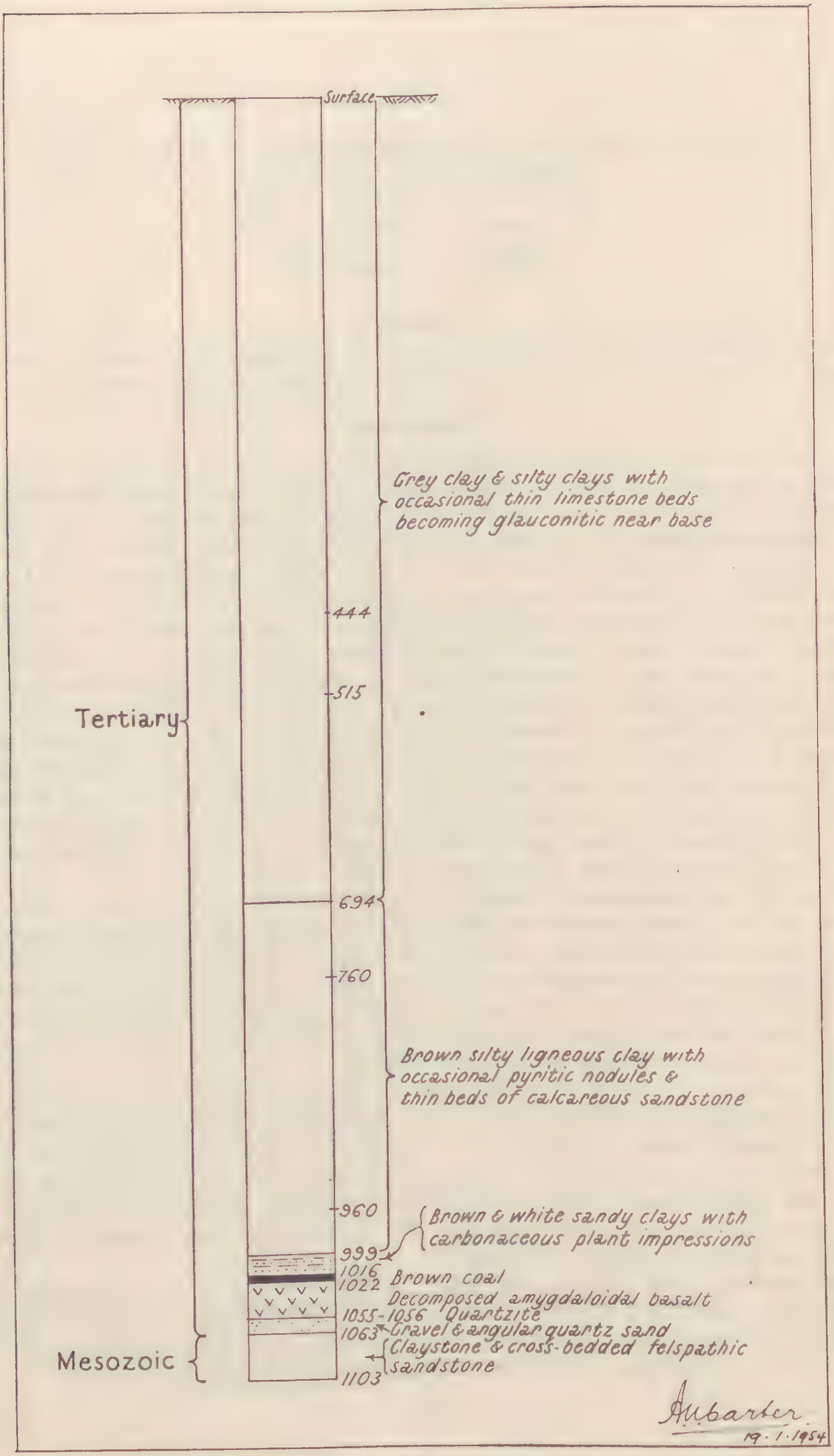

FIG. 1.—Lithological sequence in Victorian Mines Department Bore No. 1 at Birregurra, Victoria.

Microspore Content

(1) *Dark grey clays at 444-515 feet.*

Two samples were analysed, one at 444-449 feet, the other at 511-516 feet, but the pollen and spore content is too low to give an adequate idea of the flora of the period. Pollen grains of two types of *Nothofagus* (*N.* sp. *a.* and *N.* sp. *e.*, cf. Cookson, 1946) and *Triorites harrisii* Couper were observed.

The presence of foraminifera and examples of the Hystrichosphaerideae indicates an environment in which the waters were saline.

(2) *Brown ligneous clays and silts between 760-960 feet.*

Most of the information regarding the microflora preserved in this section of the core has been obtained from samples 760-761 feet and 842-843 feet, in both of which the microspore content is high and varied. The majority of the pollen grains present are small dicotyledonous types, many of which have still to be classified. Of the recognizable forms, pollen grains of *Nothofagus* spp. and *Triorites harrisii* are most frequent, with the former predominating. Several coniferous types have been observed, usually, however, in low frequencies. The following sporomorphs occur:

Bryophyta—*Sphagnites australis* f. *parva* Cookson, *S. australis* f. *crassa* Cookson.

Pteridophyta—*Gleichenia circinidites* Cookson.

Coniferae—*Araucariacites australis* Cookson, *Dacrycarpites australiensis* Cookson and Pike, *Dacrydiumites florinii* Cookson and Pike, *Microcachryidites antarcticus* Cookson, *Trisaccites micropterus* Cookson and Pike.

Dicotyledoneae—*Anacolosidites luteoides* Cookson and Pike, *Anacolosidites acutulus* Cookson and Pike, *Beaupreaidites verrucosus* Cookson, *Cupanieidites orthoteichus* Cookson and Pike, *Cupanieidites majus* Cookson and Pike, *Cupanieidites reticularis* Cookson and Pike, *Myrtaceidites eugeniioides* Cookson and Pike, *Nothofagus* spp. a, c, d, e Cookson, *Proteacidites annularis* Cookson, *Proteacidites crassus* Cookson, *Proteacidites grandis* Cookson, *Proteacidites pachypolus* Cookson and Pike, *Santalumidites cainozoicus* Cookson and Pike, *Tricolpites thomasii* Cookson and Pike, *Triorites harrisii* Couper, *Triorites magnificus* Cookson.

The occurrence of Hystrichosphaerids and Dinoflagellates indicates a continuance of the saltwater environment of the higher levels.

(3) *Brown coal situated between 1006 and 1022 feet.*

The microspore content at this level is numerically lower and less varied than that of the preceding series, and many of the sporomorphs found at the higher levels are absent. Those recognized are: *Gleichenia circinidites*, *Dacrydiumites florinii*, *Dacrydiumites mawsonii*, *Trisaccites micropterus*, *Nothofagus* spp. and *Triorites edwardsii* Cookson and Pike. Small three-aperturate types with triangular ambs are relatively abundant.

No examples of marine groups such as the Hystrichosphaerideae have been observed.

(4) *Pale grey mudstone at 1089-1092 feet.*

The microflora preserved at this level may be taken as representative of the deposits intersected at the bottom of the Birregurra bore. It consists mainly of

trilete Pteridophyte spores and some two- and three-winged pollen grains referable to the Podocarpaceae. No dicotyledonous types have been recognized. The only forms that at present can be classified in greater detail are the sporomorphs *Microcachryidites antarcticus* and *Mohriosporites australiensis* Cookson.

Vertical Distribution of Sporomorphs

Some of the sporomorphs isolated from the Birregurra core are known, from their occurrences elsewhere in Australia, to have extended from Eocene or earlier to Pliocene. Such long-range forms, which include *Sphagnites australis* f. *parva*

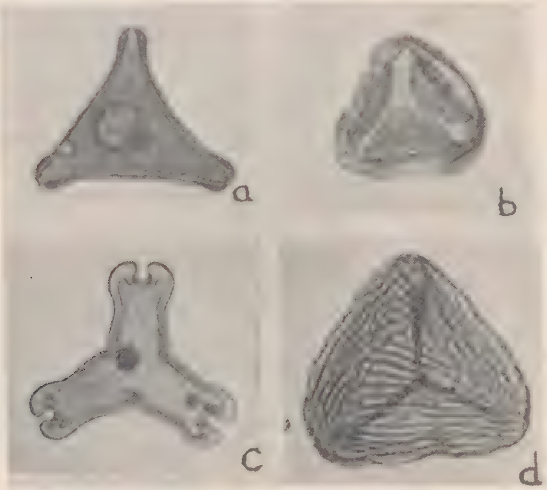

FIG. 2.—Sporomorphs characterizing the three microfloras in the Birregurra bore. a, *Proteacidites pachypolus*; b, *Trisaccites micropterus*; c, *Triorites edwardsii*; d, *Mohriosparites australiensis.*

(Cretaceous to Pliocene), *Gleichenia circinidites* (Cretaceouse to Pliocene), *Araucariacites australis* (Cretaceous to Pliocene), *Dacrycarpites australiensis* (Eocene to Pliocene), *Nothofagus* sp. *a* (Eocene to Quaternary) and *Triorites harrisii* (Eocene to Pliocene), have little stratigraphical value and are mainly of geographical and palaeo-ecological interest.

Other types, for example *Dacrydiumites mawsonii*, *Microcachryidites antarcticus* and some of the *Nothofagus* pollen types, have less clearly known limits either because of uncertainties regarding age of the deposits in which they have been found (especially lignitic freshwater series) or doubts concerning the identity and vertical distribution of the sporomorphs themselves.

However, four of the sporomorphs occurring in the Birregurra deposits, evidently with limited time-ranges, appear likely to prove useful stratigraphical indicators in the Upper Mesozoic-Lower Tertiary succession. They are: (1) *Mohriosporites australiensis*, (2) *Trisaccites micropterus*, (3) *Proteacidites pachypolus*, (4) *Triorites edwardsii.*

(1) *Mohriosporites australiensis.*

This is a characteristic type morphologically similar to spores of the fern *Mohria*, an African member of the family Schizaeaceae. It also agrees closely with the fossil *Mohriosporites dorogensis* R. Pot. and Gell. which ranges in Europe from Lower Cretaceous (Wealden) to Oligocene (Thiergart, 1949).

Mohriosporites australiensis is one of the most abundant types in the pre-basaltic section of the Birregurra bore and is especially abundant at 1089-1090 feet. It has been recorded from Mesozoic mudstones situated between 651-708 feet in the Comaum (South Australia) bore (Cookson, 1953) and has been observed in a Lower Cretaceous marine shale from Onepah Station, north of Tibooburra in north-western New South Wales, and in the Styx River series of Queensland. So far *M. australiensis* has not been found in Jurassic deposits. Dr. N. J. de Jersey has kindly permitted me to report its absence from the Jurassic coals of the Rosewood coal fields, Queensland, upon which he is working; it also appears to be absent from the Jurassic coals at Wonthaggi, Victoria.

M. australiensis has not been observed in the post-basaltic portions of the Birregurra core nor in any of the Australian Tertiary deposits hitherto examined. It therefore appears that *M. australiensis* is restricted to the Cretaceous.

(2) *Triasccites micropterus.*

This is readily distinguished from other three-winged coniferous pollen grains by its frequently triangular outline in polar view and the much reduced broadly attached bladders. It has a wide geographical distribution in Australia and ranges from the Jurassic to the Older Tertiary (Cookson and Pike, 1954).

Although the upper limit of *T. micropterus* cannot be specified, most of the Tertiary deposits in which it occurs and for which indications of age are available are regarded by geologists as being low in the sequence. This applies to the Anglesea Siltstone Member of ?Middle Eocene age, according to Raggatt and Crespin (1952); the Eastern View Coal Measures (Paleocene to Eocene, according to Raggatt and Crespin, 1952); the Wensleydale brown coal; the beds between 842 and 1020 feet in the Birregurra bore; lignite at 106-110 feet in a bore at Bambra; the Pebble Point Formation (Paleocene to Lower Eocene, Baker, 1943, 1953; Singleton, 1943; and Teichert, 1943), and the ligneous horizon between 515 and 538 feet in the Cootabarlow bore, thought to be Upper Cretaceous by Whittle and Chebotarev (1952). So far *T. micropterus* has not been observed in the pre-basaltic section of the Birregurra core, although it extends into the Mesozoic sediments at Comaum, South Australia, and is a component of the microflora of the Lower Cretaceous Styx and Burrum Coal Measures.

(3) *Proteacidites pachypolus.*

This is a characteristic sporomorph of uncertain affinity, infrequent occurrence (Cookson and Pike, 1954), and probable Eocene age. Evidence in support of such an age is provided by its occurrence in the Anglesea Siltstone, the sandy clay with *Cyclammina* at the base of the Castle Cove section, Aire Coast, Victoria, the suggested age for which is Upper Eocene or older (*vide* Dr. O. P. Singleton), and the Cootabarlow lignites, which are probably not younger than Eocene. The only beds in which it has been found that may be younger are the deep leads at Vegetable Creek, New South Wales, the age of which remains uncertain. It has not been observed in the brown coals at Bacchus Marsh and the Latrobe Valley.

The restricted distribution of *P. pachypolus* in the Birregurra bore is in keeping with the suggested Eocene age.

(4) *Triorites edwardsii.*

This is a rare type which, so far, has only been found in deposits situated in south-western Victoria and south-eastern South Australia. These are the Eastern View Coal Measures; the Benwerrin brown coal; Lal Lal, near Ballarat, in Mines Department Bore 51 at 398 feet, and in Bore 47 at 206-223 feet; the Pebble Point Formation; the Nelson bore at 3723, 3874, 4025 feet, all in Victoria; and the coal in the Comaum bore, South Australia, at 619 feet 6 inches.

All these deposits are low down in the Tertiary sequence and could be of Lower Eocene or even Paleocene age on the basis of Raggatt and Crespin's correlation of the Eastern View Coal Measures (1952, p. 146). This position and probable age is supported by the apparent restriction of *Triorites edwardsii* to the base of the post-basaltic section of the Birregurra bore, i.e. from 1006-1020 feet.

Relationships of Microfloras

Considerably more information regarding the identity and distribution of the microspore types in Australian Mesozoic and Older Tertiary deposits is necessary before full comparisons between the microfloras of these strata can be made. Nevertheless tentative conclusions regarding the relationship of some of the deposits in the Upper Mesozoic and Older Tertiary sequences can now be drawn from a comparison of microfloras in described strata of known age with those of the Birregurra succession.

It has been found that three distinct microfloras occur in the Birregurra bore and that each contains one distinctive sporomorph that seems characteristic of the sediments in which it occurs. For the present, these microfloras will be designated A, B and C.

Microflora A, occurring between 1073 and 1090 feet

This microflora is characterized by the absence of dicotyledonous pollen grains and the presence of *Mohriosporites australiensis* which, elsewhere in Australia, appears to be restricted to Cretaceous deposits. It is probable, therefore, that the sediments in this section of the Birregurra bore are also Cretaceous. For similar reasons the same age is indicated for the deposits between 651 and 708 feet in the Comaum bore, South Australia.

Mr. P. R. Kenley (personal communication) has drawn attention to the resemblance between the sediments in the Birregurra bore containing Microflora A and the Runnymede Formation in the Glenelg district in far south-western Victoria. The Runnymede Formation which lies between Jurassic and Lower Eocene or Paleocene sediments is regarded as Cretaceous (Kenley, 1954).

Microflora B, occurring between 1006 and 1020 feet

Microflora B is characterized by the incoming of coniferous types not present in Microflora A, and a limited number of dicotyledonous pollen types of uncertain affinities including *Triorites edwardsii.* This sporomorph is also known from the Eastern View Coal Measures; the Benwerrin coal; in bores at Lal Lal, at 398 and 206 to 223 feet; the Pebble Point Formation and the Nelson Bore at 3723 and 4025 feet. On the basis of the occurrence of *T. edwardsii* it is considered that the horizons mentioned contain Microflora B, and that they are all approximately of the same age, that is, Paleocene to early Eocene.

TABLE 1.—*The distribution of some of the sporomorphs in Older Tertiary deposits in South-western Victoria*

Name of Sporomorph	Microflora C.					Microflora B.			
	Birregurra Bore 760–960 feet	Anglesea Siltstone Formation	Basal Beds Castle Cove Aire Coast	Princetown Member	Clay parting in Wensleydale brown coal	Birregurra Bore 1006–1020 feet	Pebble Point Formation	Eastern View Coal Measures	Caol at Benwerrin
Araucariacites australis ..	+	+	+	+	+	+	+	+	+
Dacrycarpites australiensis ..	+	+	−	+	+	−	−	+	−
Dacrydiumites florinii ..	+	+	+	+	+	+	+	+	+
Dacrydiumites mawsonii ..	+	+	+	+	+	+	+	+	+
Microcachryidites antarcticus .	+	+	+	+	+	+	+	+	+
Trisaccites micropterus ..	+	+	+	+	+	+	+	+	+
Anacolosidites acutulus ..	+	−	+	−	+	−	−	−	−
Anacolosidites luteoides ..	+	+	+	+	−	−	−	−	−
Beaupreaidites verrucosus ..	+	+	+	+	+	−	−	−	−
Cupanieidites orthoteichus ..	+	+	+	+	+	−	−	−	+
Cupanieidites majus	+	+	−	−	−	−	−	−	−
Myrtaceidites eugeniioides ..	+	+	+	+	+	−	−	−	−
Nothofagus sp. *c*	+	+	−	+	+	−	−	−	−
Nothofagus sp. *d*	+	+	+	−	−	−	−	−	−
Nothofagus spp.	+	+	+	+	+	+	+	+	+
Proteacidites annularis ..	+	+	+	+	+	−	−	−	−
Proteacidites crassus	+	+	+	+	+	−	+	−	+
Proteacidites grandis	+	+	+	+	+	−	+	−	+
Proteacidites incurvartus ..	+	+	−	+	+	−	−	−	+
Proteacidites pachypolus ..	+	+	+	−	−	−	−	−	−
Santalumidites cainozoicus ..	+	+	+	−	−	−	−	−	−
Tricolpites thomasii	+	+	+	−	−	−	−	−	−
Triorites edwardsii	−	−	−	−	−	+	+	+	+
Triorites harrisii	+	+	+	+	+	+	−	−	−
Gleichenia circinidites (Fern) .	+	+	+	+	+	+	+	+	+
Sphagnites australis forma *parva* (Moss)	+	+	+	+	+	+	+	+	+

Microflora C, occurring between 760 and 960 feet

In Microflora C there is a marked increase in the number of dicotyledonous pollen types and such components as *Anacolosidites luteoides*, *Cupanieidites orthoteichus*, *Myrtacieidites eugeniioides* and *Santalumidites cainozoicus* can be closely compared with pollen of living species. *Triorites edwardsii* is no longer present. The index fossil chosen to characterize Microflora C is *Proteacidites pachypolus*.

It is considered that Microflora C is also present in the Anglesea Siltstone, the basal bed in the Castle Cove section, the Princetown Member of the Dilwyn Clay, the Nelson Bore at 992 feet and possibly the Wensleydale coal seam and associated clay (Table 1).

From geological considerations it is suggested that Microflora C is, in part at least, Eocene, although later in the Eocene than Microflora B. At present no indications can be given for its upper limits.

Comparison of the Birregurra (760-960 feet) with other Microfloras

Anglesea

The components of these two microfloras are closely similar, even such rare examples as *Anacolosidites luteoides*, *Cupanieidites majus*, *Santalumidites cainozoicus* and *Tricolpites thomasii* being common to both. Moreover, each has a high and varied microspore content which includes *Proteacidites pachypolus* and *Trisaccites micropterus*. There is thus a strong indication that the two deposits belong to the same horizon.

Basal Clays of the Castle Cove Section

The sporomorph *Proteacidites pachypolus* selected as characterizing this portion of the Birregurra core is occasionally found in the microspore assemblage in the Castle Cove clay. The affinity between these deposits is further supported by the occurrence of *Trisaccites micropterus* and examples of *Anacolosidites acutulus*, *Anacolosidites luteoides*, *Santalumidites cainozoicus* and *Tricolpites thomasii*.

Wensleydale

This correlation is not quite so exact as the previous ones owing to the apparent absence from the Wensleydale coal and clay parting of the sporomorphs *Proteacidites pachypolus*, *Anacolosidites luteoides*, *Santalumidites cainozoicus* and *Tricolpites thomasii*. The most characteristic and conspicuous type in the Wensleydale deposits in *Proteacidites grandis*. This form has been observed also, although less frequently, in residues of the sediments at Birregurra (760-960 feet), Anglesea, Castle Cove, and of the Princetown Member. *Trisaccites micropterus*, *Anacolosidites acutulus* and *Beaupreaidites verrucosus* are three sporomorphs of apparently limited vertical range common to Wensleydale and Birregurra.

Princetown Member of the Dilwyn Clay

The microspore content of the Princetown Member is neither so high nor so varied as that of the other deposits mentioned. As far as can be judged at present it differs from the assemblage at Birregurra principally in the absence of *Proteacidites pachypolus*, *Santalumidites cainozoicus* and *Tricolpites thomasii*.

Stratigraphical Significance

Independent evidence is available for the succession of the microfloras described from the Birregurra bore. In the Nelson bore Microflora B is present at 3723 and 4025 feet, and C occurs at 992 feet. In the Moonlight Head-Princetown sequence, B occurs in the basal Pebble Point Formation and C in the overlying Dilwyn clay and the Princetown member of this formation. In the Eastern View-Anglesea sequence, B characterizes the Eastern View Coal Measures and C the overlying Anglesea Siltstone. There is little doubt, therefore, that the three microfloras are distinct and of stratigraphical significance. This being so, they provide a basis, even if an inexact one, for correlation of some of the Cretaceous and older Tertiary deposits of western Victoria and contiguous parts of South Australia.

The only correlation, instanced above, that is at variance with geological observations is that between the Wensleydale coal seam and the marine Anglesea Siltstone and beds of similar lithology between 760 and 960 feet in the Birregurra bore. As stated above, the microflora at Wensleydale differs somewhat from other microfloras referred to C, so that even on palynological grounds there is reason for doubting the reliability of this association. It has already been shown that the microflora of the Wensleydale coal has much in common with the Comaum coal at 619 feet 6 inches (*loc. cit.*) which on account of the association of *T. edwardsii* with pollen grains of definite myrtaceous and proteaceous affinities appears to be intermediate in character between Microfloras B and C.

Acknowledgements

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Royal Society of Victoria

1954

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LIST OF MEMBERS

WITH THEIR YEAR OF JOINING

[Members and Associates are requested to send immediate notice of any change of address to the Honorary Secretary.]

Life Members

Baker, George, M.Sc., Geology Department, The University, Carlton, N.3 1935
Balfour, Lewis J., B.A., M.B., B.S., 62 Hopetoun Road, Toorak, S.E.2 1892
Bonython, C. W., B.Sc., Romalo House, Romalo Avenue, Magill, South Australia .. 1945
Cudmore, F. A., 12 Valley View Road, East Malvern, S.E.6 1920
Ferguson, W. H., 37 Brinsley Road, East Camberwell, E.6 1894
Gault, E. L., M.A., M.B., B.S., 2 Collins Street, Melbourne, C.1 1899
Osborne, Prof. W. A., M.B., B.Ch., D.Sc., "The Hall," Kangaroo Ground 1910
Reid, J. S., "Green Hedges," Somers 1920
Rogers, J. S., M.C., B.A., D.Sc., F.Inst.P., The University, Carlton, N.3 1924
Stillwell, F. L., O.B.E., D.Sc., 44 Elphin Grove, Hawthorn, E.2 1910
Summers, H. S., D.Sc., 1 Winson Green Road, Canterbury, E.7 1902
Withers, R. B., M.Sc., Dip.Ed., Food Preservation Research Laboratories, Private Bag, Homebush, N.S.W. 1926

Ordinary Members

Adams, L., 111 Ferrars Street, South Melbourne, S.C.4 1946
Alexander, G. N., Bayview Road, Belgrave 1951
Anderson, George, M.A., LL.M., M.Com., Litt.D., 54 Winton Road, East Malvern, S.E.5 1924
Anderson, V. G., 360 Collins Street, Melbourne, C.1 1943
Bain, A. D. N., D.Sc., F.G.S., 69 Windella Avenue, East Kew, E.5 1950
Baragwanath, W., O.B.E., 327 Orrong Road, East St. Kilda, S.4 1922
Barrett, A. O., 1 Queen Street, Melbourne, C.1 1908
Bate, E., B.Sc. (Eng.), 20 St. George's Avenue, Mont Albert, E.10 1954
Beasley, A. W., M.Sc., Ph.D., National Museum, Russell Street, Melbourne, C.1 .. 1950
Blackburn, Maurice, M.Sc., C.S.I.R.O., Fisheries Division, Cronulla, N.S.W. 1936
Boardman, W., M.Sc., Zoology Department, The University, Carlton, N.3 1947
Boutakoff, N., D.Sc. (Louvain), Mines Department, Melbourne, C.2 1950
Brumwell, C. Stanley, 24 Miami Street, Hawthorn, E.3 1946
Brunn, T. H., 366 St. Kilda Road, Melbourne, S.C.1 1953
Buley, J. O., B.Sc., Engineering School, The University, Carlton, N.3 1946
Campbell, H. A. M., Cliveden Mansions, 192 Wellington Parade, East Melbourne, C.2 1945
Casey, D. A., M.C., F.S.A., "Murraba," Coldstream 1932
Cherry, Prof. T. M., B.A., Ph.D., Sc.D., The University, Carlton, N.3 1930
Chinner, J. H., B.Sc. (Oxon and Melb.), Dip.For., School of Forestry, The University, Carlton, N.3 1950
Clark, A. M., M.Sc., Ph.D., Zoology Department, The University, Carlton, N.3. .. 1940
Clark, G. Lindesay, M.C., B.Sc., M.M.E., Gold Mines of Australia Ltd., P.O. Box 860K, Melbourne, C.1 1931
Colliver, F. S., Geology Department, University of Queensland, Brisbane, Queensland 1933
Coulson, A., M.Sc., 5 Victoria Street, Preston, N.18 1929
Cox, Leonard B., M.D., B.S., M.R.C.P., 719 Toorak Road, Malvern, S.E.4 1946
Davis, J. K., "Dundrennan," 492 St. Kilda Road, Melbourne, S.C.2 1920
Dawes, L., B.Sc., 43 Hopetoun Grove, Ivanhoe, N.21 1954
Devine, John, M.S., F.R.C.S., 57 Collins Street, Melbourne, C.1 1945
Drummond, F. H., Ph.D., B.Sc., Zoology Department, The University, Carlton, N.3 .. 1933
Edwards, A. B., D.Sc., Ph.D., D.I.C., Geology Department, The University, Carlton, N.3 1930

Esserman, N. A., B.Sc., A.Inst.P., National Standards Laboratory, University Grounds, Sydney, N.S.W. 1923
Fitts, Clive H., M.D., 14 Parliament Place, Melbourne, C.2 1945
Focken, C. M., B.Sc., B.M.E., Ph.D. (Oxon), M.S. (Colorado School of Mines), 20 Carson Street, Kew, E.4 1952
Garran, R. R., M.Sc., Ph.D., F.R.A.C.I., c/o I.C.I.A.N.Z., 380 Collins Street, Melbourne, C.1 1954
Gill, Edmund D., B.A., B.D., 26 Winifred Street, Essendon, W.5 1938
Gray, K. Washington, M.A. (Cantab.), Ph.D. (Vienna), F.G.S., F.Inst.Pet., 1 Berenice Terrace, Toorak, S.E.2 1946
Grice, J. Hugh, "Highfield," Lilydale 1938
Grimwade, Sir Russell, Kt.B., C.B.E., B.Sc., 342 Flinders Lane, Melbourne, C.1 .. 1912
Hanks, W., 7 Lake Grove, Coburg, N.14 1930
Harding, N. T., B.M.E., 34 Wakefield Street, Hawthorn, E.2 1951
Hartman, S., c/o The James Bell Machinery Co. Pty. Ltd., 200 King St., Melbourne, C.1 1946
Hartung, Prof. E. J., D.Sc., Ph.D., Lavender Farm, Woodend 1923
Heath, H. J., 25 Lyndhurst Crescent, Hawthorn, E.2 1951
Hills, Prof. E. S., D.Sc., Ph.D., F.R.S., The University, Carlton, N.3 1928
Hird, F. J. R., M.Agr.Sc., Ph.D. (Cantab.), 27 Lucerne Crescent, Alphington, N.20 .. 1951
Hordern, A., 242 Walsh Street, South Yarra, S.E.1 1940
Jack, R. Lockhart, B.E., D.Sc., F.G.S., 54 Clowes Street, South Yarra, S.E.1 1931
James, A. V. G., B.A., D.Sc., 23 Bayview Crescent, Black Rock, S.9 1917
Jutson, J. T., D.Sc., LL.B., 9 Ivanhoe Parade, Ivanhoe, N.21 1902
Kannaluik, W. G., D.Sc., Physics Department, The University, Carlton, N.3 1946
Kimpton, V. Y., 16 Lansell Road, Toorak, S.E.2 1946
Knight, J. L., B.Sc., Mines Department, Melbourne, C.2 1944
Lang, P. S., B.Agr.Sc., Titanga, Lismore 1938
Langdon, H. C. C., 411 Beach Road, Beaumaris, Vic. 1954
Leeper, Assoc. Prof. G. W., M.Sc., Chemistry Department, The University, Carlton, N.3 1931
Lewis, Essington C. H., c/o Broken Hill Proprietary Ltd., 422 Little Collins Street, Melbourne, C.1 1945
Lewis, J. M., D.D.Sc., "Whitethorns," Boundary Road, Burwood, E.13 1921
McAndrew, J., B.Sc., Ph.D., C.S.I.R.O., Geology Department, The University, Carlton, N.3 1953
MacCallum, Sir Peter, M.C., M.A., M.Sc., M.B., Ch.B., D.P.H., 91 Princess Street, Kew, E.4 1925
McCausland, M. E. R., 10 Glyndebourne Avenue, Toorak, S.E.2 1953
McConnan, Sir Leslie, 189 Kooyong Road, Toorak, S.E.2 1951
McPherson, Sir Clive, C.B.E., 216 Domain Road, South Yarra, S.E.1 1946
Manning, C. T., "Glanmire," 496 St. Kilda Road, Melbourne, S.C.2 1950
Martin Prof, L. H., Ph.D., F.Inst.P., The University, Carlton, N.3 1945
Medley, Sir John, Kt.B., M.A., "Wickham," Harkaway, via Berwick 1945
Miller, E. Studley, 396 Flinders Lane, Melbourne, C.1 1921
Miller, Leo F., "Moonga," Power Avenue, Malvern, S.E.4 1920
Millikin, C. R., M.Agr.Sc., Plant Research Laboratory, Swan Street, Burnley, E.1 .. 1941
Mitchell, L. J. C., M.D., 2 Collins Street, Melbourne, C.1 1954
Montgomery, J. N., c/o Australasian Petroleum Company, 37 Queen Street, Melbourne, C.1 1945
Moore, K. Byron, 11 Mona Place, South Yarra, S.E.1 1945
Morrison, P. Crosbie, M.Sc., Melbourne, C.1 1938
Murphy, H. D., Mornington 1950
Nicholas, George R., 48 Lansell Road, Toorak, S.E.2 1934
Olsen, C. O., B.A., Dip.Ed., 46 Clendon Road, Toorak, S.E.2 1945
Orr, R. Graeme, M.A., B.Ch., 9 Heyington Place, Toorak, S.E.2 1935
Patton, R. T., D.Sc., M.F. (Harv.), D.I.C., 13 Hartley Avenue, Caulfield, S.E.8 .. 1922
Pescott, R. T. M., M.Agr.Sc., F.R.E.S., National Museum, Russell Street, Melbourne, C.1 1944
Pitt, E. R., B.A., F.L.A., "Corrabert", 210 Orrong Road, Toorak, S.E.2 1946
Preston, H. E., 47 Haig Street, Box Hill South, E.11 1949
Quayle, E. T., B.A., 27 Collins Street, Essendon, W.5 1920
Reid, J. T., "Sherwood", 7 Tregarron Avenue, Kew, E.14 1954
Rivett, Sir David, K.C.M.G., M.A., D.Sc., 474 St. Kilda Road, Melbourne, S.C.2 .. 1911

Robinson, T. J., M.Sc. (Agr.) (W.A.), Ph.D. (Cantab.), Trinity College, Carlton, N.3 1951
Sayce, E. L., B.Sc., F.Inst.P., Research and Development Branch, Department of Supply, 339 Swanston Street, Melbourne, C.1 1924
Simpson, H. P., 8 Knutsford Street, Balwyn, E.8 1948
Spicer, P. O., 6 Inverness Way, Balwyn, E.9 1946
Stokes, Dr. H. Lawrence, 417 St. Kilda Road, Melbourne, S.C.2 1945
Sullivan, W., 326 Exhibition Street, Melbourne, C.1 1943
Sunderland, Prof. S., D.Sc., M.B., B.S., The University, Carlton, N.3 1945
Tattam, C. M., Ph.D., D.Sc., Geology Department, The University, Carlton, N.3 .. 1945
Teichert, C., D.Sc., Fuels Branch, United States Geological Survey, Federal Centre, Denver, Colorado, U.S.A. 1945
den Tex, Dr. E., Ph.D. (Leyden), 13 Asquith Street, Box Hill, E.11 1952
Thomas, D. E., D.Sc., Mines Department, Melbourne, C.2 1929
Thompson, G. T., 43 Weybridge Street, Surrey Hills, E.10 1953
Tiegs, Prof. O. W., D.Sc., F.R.S., The University, Carlton, N.3 1925
Timcke, E. W., 15 Faircroft Avenue, Glen Iris, S.E.6 1950
Tindale, B., F.R.M.S., Yarra Junction 1951
Townsend, Professor S. L., M.B., B.S., F.R.C.S. (Edin.), Department of Obstetrics and Gynaecology, The University, Carlton, N.3 1951
Tulloh, N. M., B.Agr.Sc., Animal Health Laboratory, C.S.I.R.O., Flemington Road, Parkville, N.2 1950
Turner, Prof. J. S., M.A., Ph.D., M.Sc., The University, Carlton, N.3 1938
Wadham, Prof. S. M., M.A., Agr.Dip., The University, Carlton, N.3 1932
Wallace, R. M., 57 McCulloch Street, Nunawading 1952
Wettenhall, Dr. Roland R., "Aberfeldie," 557 Toorak Road, Toorak, S.E.2 1938
White, Dr. A. E. Rowden, 14 Parliament Place, Melbourne, C.2 1938
White, Dr. Edward R., 1 Douglas Street, Toorak, S.E.2 1951
Wilcock, A. A., B.Sc., B.Ed., Geology Department, The University, Carlton, N.3 .. 1934
Williams, Capt., J. D. L., Commonwealth Marine Branch, Box 4317, G.P.O., Melbourne 1954
Willis, A. G., M.Sc., Zoology Department, The University, Carlton, N.3 1949

Country Members

Adams, H. E., "Danedite," Weerite 1945
Baldwin, J. G., B.Sc., B.Agr.Sc., Commonwealth Research Station, Merbein 1949
Casey, Mrs. G. M., "Murraba," Coldstream 1953
Corney, Mrs. A. D., B.Sc., 17 Ratho Street, New Town, Tasmania 1945
Dickins, J. MacG., B.Sc., Bureau of Mineral Resources, Geology and Geophysics, Canberra, A.C.T. 1952
Glaessner, M. F., Ph.D., D.Sc., Geology Department, The University of Adelaide, Adelaide, South Australia 1939
Gloe, C. S., M.Sc., State Electricity Commission, Morwell 1944
Harris, W. J., B.A., D.Sc., 2 Holden Street, Beaumaris, S.10 1914
Hill, Dorothy, D.Sc., Geology Department, The University of Queensland, Brisbane, Queensland 1939
Hope, G. B., B.M.E., "Carrical," Hermitage Road, Newtown, Geelong 1918
Howe, Mrs. M. A., B.Sc., 18 Devonscourt, South End, Mt. Isa, Queensland 1948
Jenkin, J. J., 35 Marley Street, Sale 1945
Mack, G., B.Sc., Queensland Museum, Brisbane, Queensland 1943
Mann, S. F., Melbourne Club, 36 Collins Street, Melbourne, C.1 1922
Martin, Miss Gwen J., B.Sc., 101 Waterdale Road, Ivanhoe, N.21 1946
Osborne, N., c/o Australasian Petroleum Company, Port Moresby, Papua 1930
Payne, T. E. Neville, "Woodburn," Kilmore 1945
Prentice, H. J., B.Sc., Strangways 1936
Rose, F. G. G., Division of Regional Planning, Post-war Reconstruction, Canberra, A.C.T. 1944
Trebilcock, Lieut.-Col. R. E., M.C., Wellington Street, Kerang 1921
Yates, H., M.Sc., School of Mines, Ballarat 1943

Associate Members

Aitken, Miss Y., M.Agr.Sc., School of Agriculture, The University, Carlton, N.3 .. 1936
Ashton, D. H., B.Sc., Botany Department, The University, Carlton, N.3 1949
Bage, Miss F., O.B.E., M.Sc., Grove Crescent, Toowong, Brisbane, S.W.1, Queensland 1906
Baker, A. A., 52 Carlisle Street, Preston, N.18 1946
Bartlett, A. H., Kent Avenue, Croydon, Vic. 1952
Bishop, J. J., B.A., Northcote High School, St. George's Road, Northcote, N.16 .. 1950
Brazenor, C. W., National Museum, Russell Street, Melbourne, C.1 1931
Broadhurst, E., M.Sc., 457 St. Kilda Road, Melbourne, S.C.2 1930
Burke, Mrs. Lorna M., M.Sc., "Gangara," Hurstbridge 1952
Butcher, A. D., M.Sc., Fisheries and Game Department, 605 Flinders Street, Melbourne, C.1 1936
Butler, L. S. G., No. 3 Los Angeles Court, St. Kilda, S.2 1929
Buttery, S. H., 146 Highfield Road, Camberwell, E.6 1952
Canavan, F., B.Sc., c/o Broken Hill Proprietary Ltd., 422 Little Collins Street, Melbourne, C.1 1936
Carlos, G. C., 262 Tucker Road, East Ormond, S.E.14 1951
Carter, A. A. C., "Fairholm," 15 Threadneedle Street, Balwyn, E.8 1927
Carter, A. N., M.Sc., 70 Madeline Street, Burwood, E.13 1947
Chapman, Brigadier W. D., M.C.E., "Hellas," Stawell Street, Kew, E.4 1927
Chapple, Rev. E. H., The Manse, Warrigal Road, Oakleigh, S.E.12 1919
Clifford, H. T., B.Sc., Botany Department, The University, Carlton, N.3 1949
Clinton, H. F., "Whitehall," 20 Bank Place, Melbourne, C.1 1920
Coats, R. P., B.Sc., Mines Department, Adelaide, South Australia 1951
Cobbett, A. M., Oxford Close, Moorabbin 1951
Cochrane, G. W., M.Sc., Mines Department, Adelaide, South Australia 1945
Collins, A. C., 9 McDonald Avenue, Newtown, Geelong 1928
Condon, M. A., M.Sc., Bureau of Mineral Resources, Melbourne Building, Canberra, A.C.T. 1937
Cook, G. A., M.Sc., B.M.E., 58 Kooyongkoot Road, Hawthorn, E.2 1919
Cookson, Miss I. C., D.Sc., 154 Power Street, Hawthorn, E.2 1919
Court, A. B., Childs Road, Kalorama 1949
Cowen, Miss Margot E. H., B.Agr.Sc., Department of Agriculture, Palmerston North, New Zealand 1936
Crespin, Miss I., B.A., F.R.M.S., Bureau of Mineral Resources, Melbourne Building, Canberra, A.C.T. 1919
Crohn, P. W., M.Sc., 29 Kensington Road, South Yarra, S.E.1 1946
Currey, D. T., 164 Ormond Road, Elwood, S.3 1948
Dadswell, Mrs. Inez W., M.Sc., 72 Florizel Street, Burwood, E.13 1939
Down, Mrs. Mary R., B.Agr.Sc., 35 Durham Street, Heidelberg, N.22 1942
Dunn, R. A., A.A.A., A.A.I.S., 60 Mimosa Road, Carnegie, S.E.9 1946
Edwards, G. R., B.Sc., High School, Portland 1937
Elford, F. G., B.Sc., B.Ed., 76 New Street, Brighton, S.5 1929
Elford, H. S., B.E., c/o Tait Publishing Company, 349 Collins Street, Melbourne, C.1 1934
Esplan, W. A., 19 Retreat Road, Hampton, S.7 1951
Essame, J. C. L., B.A. (Camb.), Mines Department, Melbourne, C.2 1951
Fawcett, Miss Stella G. M., M.Sc., Botany Department, The University, Carlton, N.3 1937
Finlay, Miss C. J., B.Sc., Geology Department, University of Melbourne, Carlton, N.3 1950
Fisher, Eileen E., Ph.D., 1 Balwyn Road, Canterbury, E.7 1949
Forster, H. C., B.Agr.Sc., Ph.D., 2 Belmont Avenue, Balwyn, E.8 1938
Frostick, A. C., 9 Pentland Street, North Williamstown, W.16 1933
Gaskin, A. J., M.Sc., 1110 White Horse Road, Box Hill, E.11 1941
Gladwell, R. A., 79 Cochrane Street, Elsternwick, S.4 1938
Glenister, B. F., B.Sc., Geology Department, University of Western Australia, Perth, W.A. 1950
Gordon, Alan, B.Sc., c/o C.S.I.R.O., Yarra Bank Road, South Melbourne, S.C.4 .. 1938
Goudie, A. G., B.Agr.Sc., Horticultural Research Station, Tatura 1941
Gunson, Miss Mary, M.Sc., Zoology Department, The University, Carlton, N.3 1944
Hardy, A. D., 24 Studley Avenue, Kew, E.4 1913
Hauser, H. B., M.Sc., Geology Department, The University, Carlton, N.3 1919
Haycraft, J. A., 27 Yeovil Road, Burwood, E.13 1951
Head, W. C. E., 40 The Strand, Williamstown, W.16 1931

Heysen, Mrs. D., P.O. Box 10, Kalangadoo, South Australia 1935
Hill, R. D., D.Sc., Physics Department, University of Illinois, Urbana, Ill., U.S.A. .. 1946
Hogan, T. W., M.Agr.Sc., 25 Devon Street, Box Hill South, E.11 1947
Holland, R. A., 526 Toorak Road, Toorak, S.E.2 1931
Holmes, A. J., B.Sc., Charles Street, Castlemaine 1949
Holmes, W. M., M.A., B.Sc., 1 Balmoral Avenue, Kew, E.4 1913
Honman, C. S., B.M.E., 3 Fairy Street, Ivanhoe, N.21 1934
Jack, A. K., M.Sc., 49 Aroona Road, Caulfield, S.E.7 1913
Jessep, A. W., B.Sc., M.Agr.Sc., Botanical Gardens, South Yarra, S.E.1 1927
Jones, D. Spencer, B.Sc., 31 Winmalee Road, Balwyn, E.8 1952
Jones, L. H. P., M.Sc., Ph.D., Chemistry Department, The University, Carlton, N.3 .. 1948
Kenley, P. R., B.Sc., 4 Anthony Street, Ormond, S.E.14 1948
Kenny, J. P. L., B.C.E., 38 College Street, Elsternwick, S.4 1942
Langtry, J. O., 15 Boston Road, Balwyn, E.8 1950
Law, P. G., M.Sc., Antarctic Division, Department of External Affairs, 187 Collins Street, Melbourne, C.1 1946
Lindholm, J. D. E., 92 Victoria Street, Carlton, N.3 1952
Lindner, A. W., B.Sc., c/o West Australian Petroleum Pty. Ltd., Box L 898, G.P.O., Perth, W.A. 1949
Lord, E. E., 77a Durham Road, Surrey Hills, E.10 1950
Lynch, D. D., 179 Park Street, Parkville, N.2 1950
McLennan, Assoc. Prof. Ethel, D.Sc., The University, Carlton, N.3 1915
McNally, J., B.Sc., Fisheries and Game Department, 605 Flinders Street, Melbourne, C.3 1950
MacPherson, Miss J. Hope, B.Sc., National Museum, Russell Street, Melbourne, C.1 .. 1940
Manning, N., 733 Punt Road, South Yarra, S.E.1 1940
Marsden, M. A. H., 68 Champion Street, Middle Brighton, S.5 1952
Mitchell, A. W. L., B.Sc., 77 Illawarra Road, Hawthorn, E.2 1946
Mitchell, S. R., 22 Grosvenor Street, Abbotsford, N.9 1945
Morris, P. F., National Herbarium, South Yarra, S.E.1 1921
Moy, A. F., B.A., Melbourne Boys' High School, Forrest Hill, South Yarra, S.E.1 .. 1943
Mushin, Mrs. Rose, M.Sc., Bacteriology Department, The University, Carlton, N.3 .. 1940
Neilson, J. L., 1 Fordham Avenue, Camberwell, E.6 1952
Nye, E. E., College of Pharmacy, 360 Swanston Street, Melbourne, C.1 1932
Oke, C., 34 Bourke Street, Melbourne, C.1 1922
Pike, Miss K. M., B.Sc., Botany Department, The University, Carlton, N.3 1948
Pinches, Mrs. M., 5A Second Avenue, North Williamstown 1943
Pretty, R. B., M.Sc., 62 Glen Iris Road, Glen Iris, S.E.6 1922
Rigby, J. F., Holland Road, Blackburn 1953
Rimington, K. N., B.Sc., 15 Yuille Street, Brighton, S.5 1948
Rowney, George, B.Sc., 4 Riddle Street, Bentleigh, S.E.14 1952
Schleiger, N. W., B.Sc., B.Ed., High School, Seymour 1949
Seeger, R. C., 56 Jenkins Street, Northcote, N.16 1946
Shaw, N. J., 192 Victoria Street, West Brunswick, N.12 1950
Sherrard, Mrs. H. M., M.Sc., 43 Robertson Road, Centennial Park, N.S.W. 1918
Shipp, A., "Gangort," Canterbury Road, Heathmont 1946
Singleton, O. P., M.Sc., Geology Department, University of Western Australia, Nedlands, W.A. 1943
Stach, L. W., M.Sc., 78 Herbert Street, Albert Park, S.C.6 1932
Thomas, G. A., B.Sc., 39 Duffy Street, Ainslie, Canberra, A.C.T. 1944
Thomas, L. A., B.Sc., C.S.I.R.O., Stanthorpe, Queensland 1930
Tubb, J. A., M.Sc., Department of Biology, Hong Kong University, Hong Kong 1936
Tugby, D. J., National Museum, Russell Street, Melbourne, C.1 1949
Tylee, A. N., 31 Wingan Avenue, Camberwell, E.6 1951
Vasey, G. H., B.C.E., The University, Carlton, N.3 1936
White, D. A., B.Sc. (W.A.), Bureau of Mineral Resources, Geology and Geophysics, Canberra, A.C.T. 1951
White, Miss Lillian, B.Sc., Royal Merchant Navy College, Bear Wood, Wokingham, Berks., England 1947
Whitehead, Mrs. Sylvia, M.Sc., 48 Invermay Grove, Rosanna 1942
Woodburn, Mrs. Fenton, 21 Bayview Crescent, Black Rock, S.9 1930
Wymond, A. P., M.Sc., Division of Forest Products, C.S.I.R.O., P.O. Box 18, South Melbourne, S.C.4 1951

Royal Society of Victoria

ANNUAL REPORT OF THE COUNCIL FOR THE YEAR 1953

The President and Council present to members of the Society the Annual Report and Statement of Receipts and Expenditure for the year 1953.

The following meetings of the Society were held:

March 12th.—Annual Meeting. The following office-bearers were elected: *President*, Dr. F. L. Stillwell; *Vice-Presidents*, Professor L. H. Martin, Professor E. S. Hills; *Honorary Treasurer*, Mr. R. T. M. Pescott; *Honorary Librarian*, Mr. F. A. Cudmore; *Honorary Secretary*, Associate Professor C. M. Tattam; *Members of Council*, Mr. L. Adams, Mr. W. Baragwanath, Mr. D. A. Casey, Captain J. K. Davis, Mr. E. R. Pitt, Professor O. W. Tiegs, Professor J. S. Turner, Professor S. M. Wadham.

The following *Members of Council* continued in office: Mr. V. G. Anderson, Associate Professor G. W. Leeper, Dr. D. E. Thomas, Professor G. L. Wood.

The Annual Report and Financial Statement for 1952 were read and adopted.

At the close of the Annual Meeting an Ordinary Meeting was held. Lecture: "The Flora of the Victorian Lower Jurassic", by Mrs. Lorna M. Burke.

April 9th.—Papers: "The Occurrence of Cretaceous Sediments in South-western Victoria", by P. R. Kenley; "Fossil Plants from Killara, Victoria", by Lorna M. Medwell; "The Geology of the Strathbogie Igneous Complex, Victoria", by D. A. White.

May 14th.—Lecture: "Industrial Power Developments in South Australia and Western Australia: Sub-bituminous Coal and Uranium", by Professor G. L. Wood.

June 18th.—Lecture: "Some Impressions of the Australian Flora", by Dr. R. Melville (Royal Botanic Gardens, Kew).

July 9th.—Papers: "Upper Murray River and Opposed Drainage Slopes", by R. A. Keble; "The Basalts, Granitic Rocks and Physiography of the Ballarat District", by H. Yates.

August 13th.—Lecture: "The Third French Antarctic Expedition", by Mr. Robert Dovers. Dr. H. S. Summers was elected a *Member of Council* to fill the vacancy caused by the death of Professor G. L. Wood.

September 10th.—Lecture: "Recent Exploration for Fossil Mammals in South Australia", by Dr. R. A. Stirton (University of California).

October 8th.—Lecture: "Botany as an Exact Science", by Dr. D. J. Carr.

November 12th.—Special General Meeting. Amendments to the Laws of the Society were submitted and adopted.* At the close of the Special General Meeting an Ordinary Meeting was held. Lecture: "Some Research Problems in Agricultural Engineering", by Mr. G. H. Vasey.

**Amendments:*

Law 22. Line 1. delete "two guineas annually . . . . . one guinea annually" and substitute "three guineas annually. Country Members and Associates shall pay two guineas annually."

Law 23. Line 5. delete "thirty guineas . . . . fifteen guineas" and substitute "forty-five guineas and a Country Member may compound similarly by paying thirty guineas." Line 10. delete "one guinea" and substitute "one and one-half guineas". Line 11. delete "five guineas" and substitute "seven and one-half guineas".

December 10th.—Papers: "Devonian Corals from Waratah Bay, Victoria", by Dorothy Hill; "Note on Devonian Limestones between the Bluff and Bird Rock, Waratah Bay, Victoria", by Curt Teichert; "Palynological Examination of No. 1 Bore Core, Birregurra, Victoria", by Isabel C. Cookson.

During the year five members, one country member and two associates were elected. One associate resigned. The total membership of the Society on December 31st, 1953, was 264.

The Council deeply regrets the loss by death of two members, one country member, and one associate.

Ernest Willington Skeats, D.Sc., A.R.C.S., F.G.S., was born at Southampton, England, on November 1st, 1875. He was educated at Handel College and Hartley College, Southampton, and at the Royal College of Science, London, where he obtained a first class Associateship in Chemistry in 1896 and in Geology in 1897. He graduated B.Sc. of London University in 1899, and D.Sc. in 1902. He was appointed Professor of Geology and Mineralogy in the University of Melbourne in 1904 and held the Chair till his retirement in 1941, when he was created Emeritus Professor in recognition of his long and able service to the University. He preserved a keen interest in the life of the University, being Dean of the Faculty of Science from 1910 to 1915, President of the Professorial Board from 1922 to 1924 and President of the Sports Union from 1920 to 1941. He was Victorian representative on the Australian National Research Council for many years and was an active member of the Australasian Institute of Mining and Metallurgy. He was awarded the Clarke Medal of the Royal Society of New South Wales in 1921, and the Mueller Medal of the Australian and New Zealand Association for the Advancement of Science in 1937.

His interests included all branches of geology, but petrology was his particular field. Before coming to Australia he had made a notable contribution on the process of dolomitization. In Victoria he is best known for his work on the Cambrian rocks of Heathcote, and on the Devonian and Tertiary igneous rocks of the Macedon district in which he collaborated with H. S. Summers. He also studied, among other things, the Woods Point Dykes, various alkaline dyke rocks, and australites. He was a fine lecturer and his ability for clear thinking and expression made him a relentless but valued critic. He was particularly interested in mining geology and his wide travels enabled him to acquire first-hand knowledge of many of the world's important mining fields which he passed on to his students.

He was elected a member of the Society in 1905 and from then on till the last year of his life was active in its affairs. He served on the Council from 1906 till his death, rarely missing a meeting unless away from Melbourne, except in his closing years when his health had given way. He was President from 1910 to 1912 and in later years a Trustee. He has been one of the outstanding figures of the Society and his deep and abiding interest in its welfare is revealed by his will, through the instrument of which the Society will ultimately receive one third of his residual estate. He died January 19th.

Gordon Leslie Wood, M.A., Litt.D., was born at Launceston. He was educated in Hobart and graduated in Arts at the University of Tasmania. He taught at St. Peter's College, Adelaide, for a time. He joined the newly founded Commerce School at the University of Melbourne in 1925 and was soon pro-

moted to Senior Lecturer. In 1930 he was awarded the degree of Litt.D. and the Harbison Higinbotham prize for his book *Borrowing and Business in Australia* and was granted a Rockefeller Foundation scholarship which enabled him to study in America. Just before the war he published, in collaboration with S. M. Wadham, *Land Utilization in Australia*, this book being republished in 1950. At the outbreak of war he became Acting Professor of Economics and in 1944, when the Commerce Faculty was split into separate departments, he was appointed Professor of Commerce. He was a member of the Commonwealth Grants Commission and had been secretary of the Economic Society of Australia since 1925. His particular field was economic geography and the economic resources of Australia. Six weeks before his death he lectured to the Society on the power potentialities of the sub-bituminous coals of South and Western Australia and the uranium ores of South Australia.

He was elected a member of the Society in 1933 and a member of Council in 1950. In recent years he gave valuable advice to the Council, particularly as a member of the committee appointed to deal with the joint scheme of the Society and the Arthur Wilson Memorial Trust. He was an Honorary Auditor for several years. He died June 29th when he appeared to be recovering from an illness which had suddenly overtaken him.

WALTER TRUDINGER, B.A., was born in England in 1874 of Moravian stock. His family settled in South Australia when he was a boy and he was educated at the University of Adelaide, where he took Final Honours in both classics and mathematics. He made teaching his profession and, coming to Victoria, first taught at University High School. He became Senior Science Master at Wesley College in 1908, which position he held till 1929 when he was made Senior Master of Mathematics and Physics. He retired in 1940, but with the shortage of teachers during the war, returned to Wesley. He was a splendid teacher and a man of culture and broad learning. He was elected an Associate Member of the Society in 1918 and was a frequent attender of meetings until his death. He was a deeply religious man and his sudden death on July 18th occurred at a Presbyterian Church meeting.

REGINALD AUGUSTUS ABSALE WHITE, B.Sc., spent much of his life in Bendigo. He was educated at the Bendigo School of Mines and the University of Melbourne, from which he graduated in Science, his major subject being Geology. For a short time he taught at the old West Melbourne Technical School, but returned in 1917 to the Bendigo School of Mines where he was head of the Geology Department until his retirement and, for the last four years, Vice-Principal. He took a great interest in and put much energy into promoting the welfare of the School and his students, who are to be found in all parts of the world. He had a good knowledge of the geology of Bendigo and was always glad to impart new facts to staff and students of the Geology Department of the University visiting that city on excursions. He was elected a Country Member of the Society in 1918. He died July 26th only a few months after his retirement.

Attendances at Council meetings were as follows: Mr. Adams, 7; Mr. Anderson, 8; Mr. Baragwanath, 10; Mr. Casey, 9; Captain Davis, 9; Professor Hills, 5; Associate Professor Leeper, 7; Mr. Pescott, 9; Mr. Pitt, 7; Dr. Stillwell, 10; Dr. Summers, 2; Associate Professor Tattam, 10; Professor Tiegs, 2; Dr. Thomas, 9; Professor Turner, 5; Professor Wadham, 2; the late Professor Wood, 2; Professor Martin, 0.

During the year 2,212 volumes and parts were added to the library. Mr. F. A. Cudmore, Honorary Librarian for 27 years, has been forced to relinquish this office because of ill-health. Throughout this long period he has devoted much of his time to the library and worked with meticulous attention to detail. He has rendered the Society a great service and the Council expresses the hope that his health will soon be restored.

The extensions and renovations to the building, provided for by the Arthur Wilson Memorial Trust of the Australian Branch of the Royal College of Obstetricians and Gynaecologists in return for joint occupancy, were begun in April and were nearing completion at the end of the year. Meetings from May onwards were held at the Geology School of the University, by permission of Professor Hills. It was found necessary to close the library and discontinue the loan service for journals other than current numbers. The library has, in fact, suffered serious disorganization and much work will need to be done before it can function efficiently.

HONORARY TREASURER'S REPORT

The financial position of the Society remains very much the same as in the year 1952. Although the credit balance in the current account at December 31st, 1953 was £778.1.9 compared with £790.2.0 at the corresponding date of 1952, the financial position would not have been so satisfactory had it not been for the payment by members of a very considerable sum in arrears of subscription. I cannot stress too strongly the necessity for members to pay their subscriptions as early as possible in each financial year.

The publication of the Proceedings has continued in much the same order as previously, and with three parts of volumes still outstanding, it is expected that the greater part of the above credit balance will be absorbed in 1954.

With the virtual completion of the extensions and alterations to the Society's buildings, it is anticipated that there will be some considerable expense involved before the building is finally equipped and suited for our uses. General costs of administration of the Society's affairs have risen but little over a long period of years, and no drastic economies are possible here.

In view of the present financial position of the Society coupled with future known commitments, it was reluctantly found necessary to increase, from and inclusive of 1954, all subscriptions to the Society. The new rates, as from January 1st, 1954, are:

Members	£3.3.0 per annum
Associate members	£2.2.0 ,, ,,
Country members	£2.2.0 ,, ,,

It is hoped that members will accept this increase as a necessary measure to stabilize the financial affairs of the Society, and allow it to function in a manner comparable with earlier years.

The Society expresses its appreciation of the action of the State Government in retaining its annual grant to the Society at the figure of £500.

FINANCIAL STATEMENT FOR YEAR ENDING DECEMBER 31, 1953

RECEIPTS

Balance in Bank at 1/1/1953		£790 2 0
Subscriptions—		
Members	£194 5 0	
Associate Members	95 11 0	
Country Members	12 12 0	
Arrears paid up	212 2 0	
Advance Subscriptions	6 6 0	
		520 16 0
Rents—		
Commonwealth Government ..	£91 13 4	
Field Naturalists' Club	16 0 0	
Microscopical Society	12 0 0	
Sundries	1 0 0	
		120 13 4
Sale of Publications		49 7 2
Interest on Bonds		14 5 0
Grants and Donations—		
Sundries		133 6 0
Sundry Items		18 8
		£1629 8 2

EXPENDITURE

Salaries—		
Assistant Secretary	£27 10 0	
Assistant Editor	20 0 0	
Hallkeeper	12 0 0	
		59 10 0
Printing—		
Proceeding, Vol. 64, pt. 2, and Vol. 65, part 1	£582 10 0	
General	33 17 4	
		616 7 4
Light, Water and Gas		18 12 8
Telephone		27 19 11
Rates and Taxes		18 10 0
Subscriptions		9 5 8
Petty Cash		6 15 0
Postage		68 14 11
Meetings		14 17 11
Fire Brigade—maintenance		1 5 0
Sundries		3 2 0
Cash in hand		6 6 0
Balance in Bank at 31/12/1953		778 1 9
		£1629 8 2

R. T. M. PESCOTT, *Hon. Treasurer.*

Audited and found correct,
March 2nd, 1954.

T. M. CHERRY } *Hon.*
J. S. TURNER } *Auditors.*

SPECIAL FUNDS

HALL FUND

Balance at 1/1/1953	£73 0 2	Balance at 31/12/1953	£74 12 4
Interest to 31/5/1953	1 12 2		
	£74 12 4		£74 12 4

LIFE MEMBERSHIP FUND

Balance at 1/1/1953	£182 7 9	Balance at 31/12/1953	£186 8 2
Interest to 31/5/1953	4 0 5		
	£186 8 2		£186 8 2

HOWITT MEMORIAL FUND

Balance at 1/1/1953	£138 9 2	Balance at 31/12/1953	£143 8 7
Interest on Bond	1 18 9		
Savings Bank Interest to 31/5/1953	3 0 8		
	£143 8 7		£143 8 7

R. T. M. PESCOTT, *Hon. Treasurer.*

Audited and found correct,
March 2nd, 1954.

T. M. CHERRY }
J. S. TURNER } *Hon. Auditors.*

SPECIAL FUNDS

T. S. HALL MEMORIAL FUND

Balance at 1/1/1953	£83 9 5	Balance at 31/12/1953	£85 6 0
Interest to 31/5/1953	1 16 7		
	£85 6 0		£85 6 0

BOOK-BINDING FUND

Balance at 1/1/1953	£119 8 7	Balance at 31/12/1953	£122 1 1
Interest to 31/5/1953	2 12 6		
	£122 1 1		£122 1 1

Accounts and Pass Books relating to each of the above Funds have been severally examined and found correct, and the Bank Certificate of Possession of Bonds amounting to five hundred pounds (£500), Savings Certificates to the face value of two hundred and fifty pounds (£250), and Fixed Deposit of two hundred pounds (£200) has also been inspected.

R. T. M. PESCOTT, *Hon. Treasurer.*

Audited and found correct,
March 2nd, 1954.

T. M. CHERRY } *Hon.*
J. S. TURNER } *Auditors.*

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Brown, Prior, Anderson Pty. Ltd., Melbourne

PROCEEDINGS

OF THE

ROYAL SOCIETY OF VICTORIA

NEW SERIES
VOLUME 67

ROYAL SOCIETY'S HALL
9 VICTORIA STREET, MELBOURNE, C.1

1955

ERRATA

Article 1

Page 3, lines 42 and 43. For "Mount Ridley" read "Woody Hill".

Page 10, line 20. For "20 chains south-east" read "20 chains south-west".

CONTENTS OF VOLUME 67

PART 1 (8 August 1955)

The Papers read before the Society during 1954 and edited under the authority of the Council. The authors of the several papers are individually responsible for the accuracy of the statements made and the soundness of the opinions given therein.

Brown Prior, Anderson Pty. Ltd., Melbourne

NEWER VOLCANIC VENTS AND LAVA FIELDS BETWEEN WALLAN AND YUROKE, VICTORIA

By WALTER HANKS

[Read 8 April 1954]

Introduction

The Newer Volcanic vents between Wallan and Yuroke are located in the Shire of Broadmeadows with the exception of Hayes Hill which is in the Shire of Whittlesea. They form part of a linear series which extends from Kilmore to one mile south of Yuroke and their lava fields are considered to be the eastern end of the basaltic plain of Western Victoria. They occur at intervals of $1\frac{1}{2}$ to 3 miles forming a rough arc with a chord of 25 miles, the distance from chord to the middle of the arc (Mount Fraser) being 4 miles. The points of the arc lie about 5° west of south.

Pretty Sally Hill, 1,739 ft. (Big Hill) on the crest of the Dividing Range occurs immediately to the north where it overlies Silurian bedrock at 1,600 ft. above sea level. Pretty Sally Hill is probably a much older vent than those described since it is very decomposed and caps ridges separating valleys cut in Silurian sandstones which have been later filled by flows from vents to the south of it.

The only literature on the volcanic rocks of this district is contained in the Geological Quarter Sheets surveyed in 1856-1857 and a reference by T. S. Hart[1] which states that the old valley down which the lavas flowed was probably divided into two, mentioning Hayes Hill as the source of the lava which extends south as far as Melbourne. Hart also describes Mount Fraser and Aitkens Hill.

The map (Fig. 1) and contours are copied from the Military Map of the district. The boundaries of the lava fields of the various points of eruption are shown, the order of their age, so far as could be determined, being indicated by the number designating them, No. 1 being the oldest. The investigation revealed some unrecorded inliers of sedimentary bedrock of presumed Silurian age and granodiorite which have been mapped.

Physiography

The volcanic vents have erupted at different times over a long period and bear no relation to the present hills and valleys. Lavas from them issued over a terrain of low hills and valleys composed of sandstones and siltstones of Silurian age except in the south-west corner of the area where granodiorite of probable Upper Devonian age outcrops.

The present drainage system is immature, much of the water sinking into the lava and flowing as ground water. It is the result of repeated changes, consequent upon the volcanic activity.

The northern part of the area prior to the lava flows consisted of two valleys and their interfluves on the southern side of the Dividing Range. The gradient from Wallan to the 600 ft. contour on the western interfluve is about 43 ft. per mile over a distance of 14 miles and there is a steady gradient from the Silurian to the granodiorite on its south-west end.

Four of the vents are located on the middle interfluve which is obscured by volcanic debris. It is 1,100 ft. above sea level at Wallan, 1,150 ft. at Springs Hill,

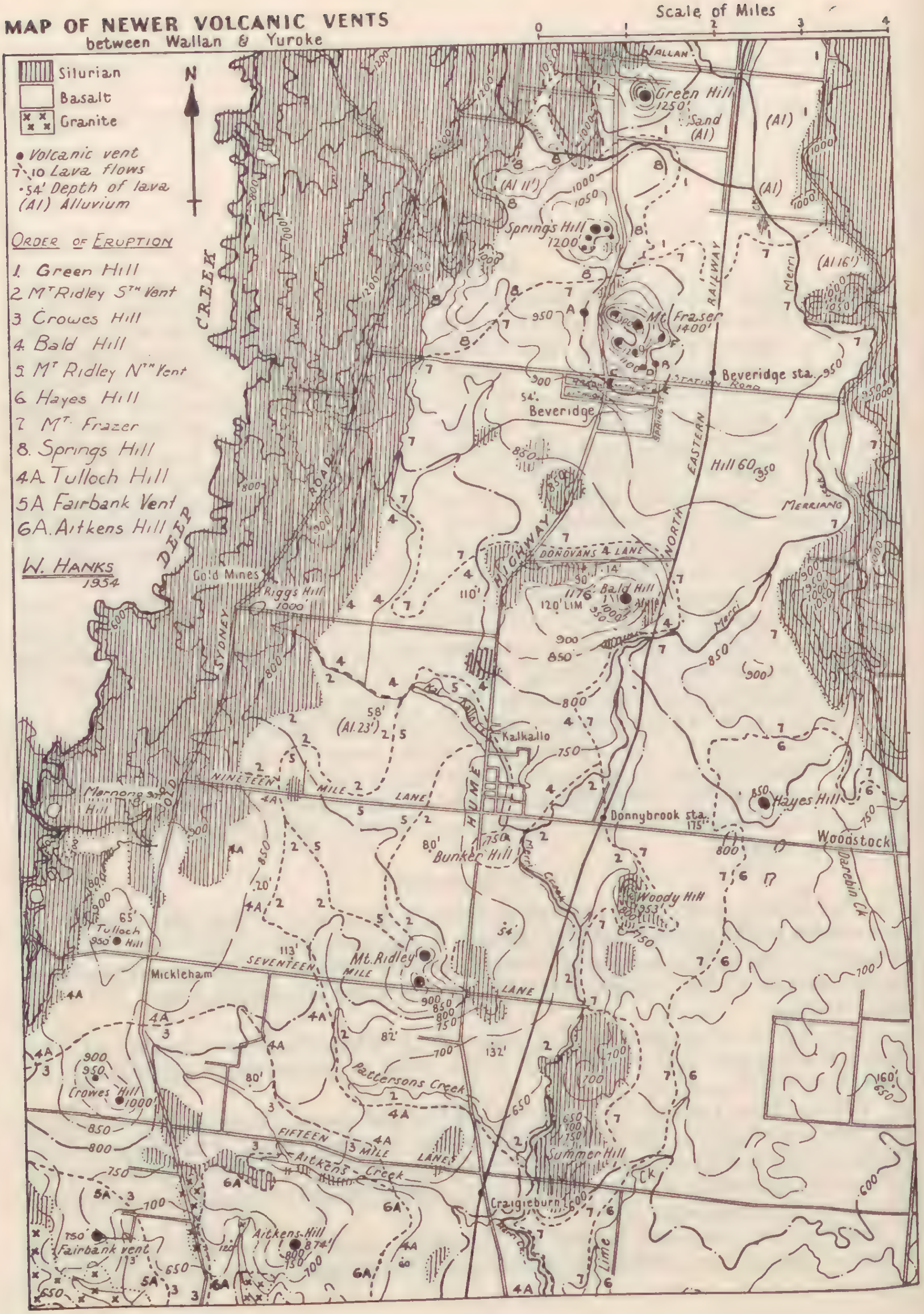
MAP OF NEWER VOLCANIC VENTS
between Wallan & Yuroke
Scale of Miles
0 1 2 3 4
Silurian
Basalt
Granite
Volcanic vent
7 10 Lava flows
54' Depth of lava
(Al) Alluvium
ORDER OF ERUPTION
1. Green Hill
2. Mt Ridley Sth Vent
3. Crowes Hill
4. Bald Hill
5. Mt Ridley Nth Vent
6. Hayes Hill
7. Mt. Frazer
8. Springs Hill
4A. Tulloch Hill
5A. Fairbank Vent
6A. Aitkens Hill
W. HANKS
1954
N
WALLAN
Green Hill 1250'
Sand (Al)
Springs Hill 1200
Mt Fraser 1400'
Beveridge sta.
STATION ROAD
Beveridge
NORTH EASTERN RAILWAY
Hill 60
MERRIANG
DONOVANS LANE
Bald Hill
HUME HIGHWAY
Gold Mines
Riggs Hill 1000
SYDNEY ROAD
DEEP CREEK
Kalkallo
NINETEEN MILE LANE
Mernong Hill
Donnybrook sta.
Hayes Hill
Woodstock
Bunker Hill
Woody Hill 953
Darebin Ck
Merri
Tulloch Hill
Mickleham
Mt. Ridley
SEVENTEEN MILE LANE
Pattersons Creek
Crowes Hill 1000'
FIFTEEN MILE LANE
Aitkens Creek
Summer Hill
Craigieburn
Fairbank vent
Aitkens Hill 874'

FIG. 1

1,000 ft. at Mount Frazer, 900 ft. south of Beveridge, 950 ft. at Bald Hill, 953 ft. at Woody Hill, 700 ft. south of it and 787 ft. at Summer Hill, a gradient of 30¼ ft. per mile in 12 miles. There is a sharp drop from Mount Ridley and Summer Hill to the 600 ft. contour.

The eastern interfluve is higher, being 1,337 ft. above sea level at Cleeves' Hill and 900 ft. three-quarters of a mile north of Woodstock where it drops sharply to the Mernda Gap.

The eastern valley was wider and deeper than the western valley and was eroded by three streams that still flow into it. The Green Hill composite volcano has diverted one stream that formerly flowed south. It has been possible to find the pre-volcanic gradient from bores. The lava at Wallan is about 50 ft. deep on the 1,000 ft. surface contour and a bore at Woolert on the 650 ft. contour shows 160 ft. of basalt. The distance between these two points is 11½ miles, giving a gradient of approximately 42 ft. to the mile. The valley narrows to 1½ miles opposite Bald Hill, and the deepest part continues through Woolert and Epping.

The western valley was much shallower and narrower. It was eroded by two streams that flowed south and emerged on to the plain through a gap three-quarters of a mile wide between the present positions of Mount Ridley and Summer Hill. Below the confluence the stream continued south on a course west of the present Merri Creek. The valley seems to have been fairly wide north of Bald Hill but there contracted to 1½ miles, again widening until it reached a point one mile north of Nineteen Mile Lane. From here its western interfluve turns south-east to Mount Ridley.

The south vent of Mount Ridley, on an eastern extension of the western interfluve, erupted and filled the gap and the lower portion of the valley, forcing the stream to cut a new passage farther east between Summer Hill and a hill south of Woody Hill into the ancient eastern valley. The next alteration to the drainage was caused by the eruption of Bald Hill on the north-east side of the middle interfluve, which here is two miles wide. It discharged lava into both eastern and western valleys, the eastern receiving a large quantity of vesicular basalt, visible only near Bald Hill but probably represented in the bed of Lime Creek, and the western a large amount of lava which spread west and south. This lava in the western valley met that from Mount Ridley, causing the stream to shift to the west and find its way between the two flows. The north vent of Mount Ridley next erupted, spreading a number of small flows about the flanks of Mount Ridley and causing a small waterfall on Kal Kallo Creek.

The next change was caused by the eruption of Hayes Hill, which is almost in the middle of the mouth of the eastern valley. Its lava covered the country to the south and east. The thickness of volcanic rocks was by this time 175 ft. just south of Hayes Hill and the big valley at Woolert had been obliterated, forcing the drainage to cut a new course on the east side of the ridge of bedrock between Bald Hill and Woody Hill, where it joined the stream flowing through the gap between Mount Ridley and Summer Hill.

Mount Frazer, on the eastern side of the middle interfluve, was the next to erupt and poured most of its lava into the eastern valley, covering part of Green Hill lava and pushing tongues towards the north. It filled the valley from wall to wall down to Hayes Hill, the lava near the vents being over 200 ft. thick. It passed Hayes Hill, filling the fairly wide and deep valley which had by this time been eroded on the west of this hill. It also filled the gap north of Summer Hill between the east and west valleys and a small valley on the east side of Hayes Hill that drained to the south-east. The filling of the eastern valley caused lava to pour over gaps between

Mount Frazer and Bald Hill in to the western valley. This lava reached Kal Kallo, filling the channels being recut, but did not cover the Bald Hill lava.

At this stage the eastern valley had nearly reached its present physiography, that is a lava-filled valley with a low-lying alluvial head, swampy in winter, from which a youthful stream, the present Merri Creek, has eroded a course on the east side of the main valley across the foot of a basalt-filled valley that lies between two ridges of bedrock. The uncovered basalt commences about midway between Wallan East and Beveridge railway station, and Merri Creek has cut a gorge about 20 ft. deep on the end of the southern ridge. The gorge is in basalt except for about 100 ft. on one bend, where it flows between bedrock and basalt. The stream continues east in basalt then turns south over an alluvial flat that is probably underlain by bedrock to Beveridge Road, where it again crosses an alluvial flat 16 ft. deep overlying basalt, until it reaches a ridge of bedrock south of Merriang. It has been deflected by lava from Mount Frazer, which banked against Hayes Hill lava, and continues on a south-westerly course across the main valley, its valley being 12 to 15 ft. deep. Reaching the south-east end of Bald Hill it flows through the Mount Frazer lava into the western valley and then south between this lava and that of Bald Hill to a point about 1½ miles from its confluence with Kal Kallo Creek. The last 1½ miles is in a south-westerly direction through an alluvial flat.

Darebin Creek developed on the east side of the eastern valley, rising in Silurian bedrock north of Woodstock and making its way southward as a mere gutter on basalt.

The western valley was brought to its present shape by the eruption of Springs Hill which is astride the middle interfluve. The eruption was not of great extent but there was sufficient lava to form a barrier 50 ft. high near the head of the valley which became swampy and filled with twelve feet of alluvium. The drainage of the main streams was diverted across the interfluve into the eastern valley. The western valley was already flat from 1½ miles south of Beveridge to Kal Kallo. At Kal Kallo there is a rise to Mount Ridley from where the gradient on the south side falls from 800 to 600 ft. above sea level in 2½ miles. The low-lying parts of the valley became one huge swamp with a depth of 25 ft. of alluvium on its western side, there being only one small tributary draining into what eventually becomes Kal Kallo Creek. This joins Merri Creek which cuts a gorge first through basalt, then between bedrock and basalt at Summer Hill, and finally in basalt before it flows on to the plain.

A feature of the western valley are large alluvial fans at the foot of the hills. A deep gully south of Marnong Hill on the old Sydney Road might in time have captured the drainage for the Maribyrnong River as the gradient of the valley to Merri Creek is almost nil and the swamps mentioned are drained by large ditches.

South from about Nineteen Mile Lane the western interfluve which to the north is Silurian bedrock widens and the bedrock is interspersed with lava. Its southern and eastern limits are defined by the 600 ft. contour. The western limits are outside the area concerned but are similarly defined.

At the southern end the present drainage is by the deep V-shaped valleys, between basalt and granodiorite, of the east and west branches of Moonee Ponds Creek, which drain southward. Before the lava flows this part of the area had been dissected by deep valleys which have since been filled with lava from Crowes Hill, Tulloch Hill, Aitken's Hill and Fairbank vent. The eastern vent of Crowes Hill was the oldest and filled valleys to the west and south by way of a valley in the Silurian bedrock on its western side, also filling one in granodiorite south of it and pouring lava flows to the east. The much younger western vent filled valleys to its west. Tulloch Hill, 1¾ miles north of Crowes Hill, is half a mile east of the valley

of the Deep Creek or Maribyrnong River and evidence of the amount of erosion which occurred between volcanic episodes and to the present day is afforded in this part of the area. The valley is over half a mile wide, the bottom being 500 ft. above sea level, the precipitous eastern edge 850 ft., and the western side, which is capped by lava older than that on the eastern side, 800 ft. above sea level. It was originally eroded on the margin of Silurian bedrock and the western basalts and a tributary about 1¾ miles long with a westerly course drained into it from the south side of Marnong Hill. Measured on the western side Deep Creek valley had reached a depth of 125 ft. when lava from Tulloch Hill flower down the tributary into it for a short distance, filling both valleys to a depth of about 30 ft. with basalt, which has since been reduced to about 25 ft. by erosion. Deep Creek has since cut a new valley between the western side and this basalt through old river gravel and bedrock beneath it to a depth of 175 ft. below the pre-basaltic bed of the creek. Marginal streams have exposed the basalt of the tributary and the gravel and bedrock underlying it and have cut through the lava that was in Deep Creek, leaving residuals north and south of the tributary the tops of which are 700 ft. above sea level. This gives some idea of the length of time between the pouring out of the lava on the western side and the Tulloch Hill eruption and also the time from this eruption to the present day.

Other valleys to the north and east which drained between Mount Ridley and Crowes Hill and then turned south to the west of Merri Creek were filled with lava from Tulloch Hill. The present bank of Merri Creek from Summer Hill is also composed of rock from this lava.

Fairbank vent is perched on the side of a valley which followed the margin of the Crowes Hill lava flows in a westerly direction. Aitkens Hill erupted on the crest of a hill near the junction of Silurian bedrock and granodiorite. It filled valleys on its east and west flanks which had been eroded since the Crowes Hill eruption.

A basalt plain extends to the south from the 600 ft. contour south-west of Summer Hill and north of Woodstock. It rises from about 550 ft. above sea level on its western side to between 550 and 700 ft. on its eastern side and is about 7 miles in width. Merri Creek flows in a course between lava flows of different ages on the western side, its valley being from 20 to 30 ft. deep and gorge-like in character. Lime Creek which rises north-east of Summer Hill flows between lavas from Hayes Hill and Mount Frazer. Darebin Creek drains the eastern side of the plain.

Description of Vents

Green Hill

Green Hill, 1,250 ft., is a point of eruption 28 miles from Melbourne on the east side of the Hume Highway. It is probably the oldest of those described. The hill of accumulation was raised on the side of what was a hill of Silurian bedrock and across the valley of a small stream that now turns east, causing a deep deposit of alluvium to form, upon part of which the town of Wallan is built. The bedrock on the north and west sides of the hill is 1,050 ft. above sea level. On the south and east there are lava flows that are partly covered by Mount Frazer and Springs Hill, the part remaining being covered by alluvium caused by the blockage of Merri Creek by lava from Mount Frazer. This alluvium is thin on its western edge near the Hume Highway but increases in depth towards the east. At a point on the creek about 27 chains east of the Hume Highway there is a bed of mingled alluvium and volcanic lapilli, which by its elevation shows that the former water level was 3 ft. higher than at present. Near the railway bridge over Merri Creek the alluvium overlies a black volcanic soil, and has a clay-pan appearance. Half a mile east of Green Hill there is a ridge of fine sandy silt raised 3 ft. above the general level that probably

represents the level before Merri Creek had cut its channel to its present depth through the Mount Frazer basalts.

Green Hill is an almost round dome rather less than half a mile in diameter, the sides of which have a slope of 10°. Brown soil fills what was probably a small crater. It is built of small basalt flows and scoria beds on the north side and flows of alkaline iddingsite basalt on the south. Olivine basalt flows issued from the south-east corner where the sides of the dome are collapsed. On the east side there is more red scoria and spatter, although towards the top are short alkaline iddingsite basalt flows. There are erosion channels on this side. The west side is composed almost wholly of flows of iddingsite limburgite which has been extensively quarried. In some places it has a peculiar globular structure and breaks into two small pieces. Its top is scoriaceous. In a small quarry on the south-west end there is a bed of black vitric cinder four feet thick underlying a lava flow. The tachylite in it has decomposed to a dull black and most has devitrified to give a yellow-brown rock. This type of bed is unusual in this district though common in western Victoria. Stearns and Macdonald[2] consider material of this kind to have been deposited by lava fountains before the lava flows.

Mount Ridley

Mount Ridley, 16½ miles from Melbourne, is situated on the west side of the Hume Highway. It has two vents, the southern and older one being 950 ft. above sea level, the northern one lying about 30 chains on a bearing of N15°E connected by a saddle and being 50 ft. lower. Both are flat domes with a slope of 5° and the base of the hill of accumulation is about one mile north and south and three-quarters of a mile east and west, decreasing around the smaller vent. There are no crater depressions but it is possible to fix the points of eruption by the spatter and by changes in the surrounding rocks. The east sides of both vents rest on the side of a hill of bedrock at the 800 ft. contour.

The southern dome is composed almost wholly of flows, its south side being olivine basalt flows and scoria beds upon which lie ejected blocks and frothy basalt. The flows, which have issued mainly from the south-west corner, have covered the countryside up to Summer Hill to a depth of 132 ft. but are overlain near Patterson's Creek by lava from Tulloch Hill. The soil on them is loamy, 10 ft. deep in places, and before ploughing was covered with buckshot gravel. There is also black soil of fair depth on the dome. The west side displays olivine basalt on the base as far as Patterson's Creek, and short thick flows of similar rocks to the summit. A bore on the summit went through 100 ft. of scoriaceous rock and then into 200 ft. of solid basalt before it was discontinued, so is probably on the vent. The east side is a viscid non-vesicular flow of olivine basalt which crosses the Hume Highway, where it is 10 ft. thick, and terminates about 200 ft. east of the road. The north side is olivine basalt as far as the saddle between the two vents and has a base built of flows of this rock from 39 to 80 ft. thick, which poured down a hillside of bedrock to the north and north-west as far as Kal Kallo Creek, where they are overlain by lava from other vents. To the north-east they reached Merri Creek and filled the gap between hills of bedrock. The creek has since cut a gorge in which is disclosed the structure of a lava flow. The top is a vesicular basalt which appears to have solidified rapidly. There is a chilled border touching the sides and bottom of the infilled valley inside which is a zone of decomposed earthy lava with small round boulders of coarse-grained non-vesicular lava in it. The earthy lava grades into a slightly vesicular pahoehoe lava, which obviously has flowed through the other. The author concludes that the earthy type was formed by accretion of semi-crystalline

lava from the pahoehoe. It was probably moving until it set and the small boulders are probably centres of crystallization.

The smaller northern dome seems to be much younger because its basalt issued in well-defined streams over the older lava. The steep top is dense limburgite, 75 ft. thick, the uppermost few feet being finely vesicular and slaggy. It consists of small phenocrysts of iddingsitized olivine in a groundmass of augite, sometimes with patches of analcite, and is well exposed in the upper quarries on the hillside. The lower quarries are in olivine basalt in which the olivine is partly iddingsitized and the groundmass is largely titanaugite, plagioclase being the minor constituent.

A bore into bedrock at a point 300 ft. east and 100 ft. north of the north-east corner of the Hume Highway and Seventeen Mile Lane disclosed a dyke at a depth of 90 ft. The dyke is thought to be much older than the volcanic rocks being described. The rock consists of zoned plagioclase the core of which is acid labradorite, laths of a normal brown hornblende with a relatively high extinction angle, and abundant groups of almost colourless amphibole aggregate which is almost certainly pseudomorphous after pyroxene. Grains of magnetite are scattered throughout and a small amount of quartz is present. The rock is mineralogically and texturally quite unlike the basalts.

Crowes Hill

Crowes Hill, 17 miles from Melbourne, is half a mile west of the junction of Fifteen Mile Lane and Old Sydney Road, Yuroke. There are two points of eruption but neither has a crater. The hill of accumulation of the main vent is an almost flat-topped dome with a slope of 5° to the sides. It is 1,000 ft. above sea level and originally had a base half a mile in diameter. On its south-east side the base rests on Silurian sandstone at an altitude of 800 ft. which is exposed in a small dam on the west side of Old Sydney Road. The northern and eastern sides of the hill consist of consolidated scoria. Immense flows of olivine basalt have issued from the base of the south and west sides and overlying these are short rough flows of alkaline olivine basalt which show abrupt ends on the west side. The summit on the east side is covered with spatter and cellular pumice and a deep well near the centre penetrates pahoehoe normal and alkaline olivine basalts. The final flow of olivine basalt from the summit poured down the north-east corner and covered the country with pahoehoe lava to the north and east.

The smaller vent lies N39°W of the main vent and is 950 ft. above sea level. It has piled up a cone on the side of the main dome, the combined base of the vents being a mile long and half a mile wide. It is a lava plug surrounded by spatter and short flows of alkaline olivine basalt, there being a large amount of lithic scoria on the north side of the vent.

These vents are among the oldest, and deep valleys have been eroded in the lava flows which poured south down ancient valleys on both sides of the granodiorite into Broadmeadows, Glenroy, Pascoe Vale, Brunswick and Carlton districts. The soil is deep and covered with buckshot gravel. The lava on the north and east sides of both vents is partly covered with that from Tulloch Hill.

Bald Hill

Bald Hill is a prominent landmark about 1½ miles east of the Hume Highway between Kal Kallo and Beveridge. The point of eruption is not as large as the size of the hill suggests as it is on a hill of Silurian bedrock 1,000 ft. above sea level, which on the east has a slope of 20°. To the west it slopes at about 5°, extending across the Hume Highway. The point of eruption is about 30 chains in diameter

and is composed mainly of red consolidated scoria which rests on basaltic lava that has flowed into valleys on its east and south-west sides. A stiff, non-vesicular flow of alkaline limburgitic olivine basalt issued on its western side. This is exposed in a quarry near the Highway and is more than 120 ft. thick at a well three-quarters of a mile from it. The rock consists of completely iddingsitized olivine phenocrysts, augite phenocrysts and groundmass, poikilitically enclosed in relatively large anhedral optical units of a felspar showing occasional imperfectly developed albite twinning and possessing variable refractive indices between the limits of 1·550 and 1·536. This is probably a high temperature oligoclase in which potash may be present. Although the chemical composition of the rock would be that of an alkaline olivine basalt it has the character of a limburgite with a great excess of alkali felspar. The top of the point of eruption consists of short flows of analcite limburgite.

The summit of Bald Hill, 1,176 ft. above sea level, has a small crater almost filled with brown soil. A bore on the 900 ft. contour 100 yds. north of the outcrop of bedrock on the east side of the hill penetrated bedrock under 35 ft. of scoria. Vesicular, black basaltic lava poured down the north-east corner of the hill to the north and east, most of it later being covered by Mount Frazer lava. Information from some bores on this side of the hill is worth recording. On Congram's Road, which runs south from Donovan's Lane, and about 100 yds. from the Lane, a bore disclosed 14 ft. of basalt and below it bedrock soil containing much quartz. Another at the end of Congram's Road on the 900 ft. contour passed through scoria and ash, finishing in bedrock at 90 ft. One on Tolmie's property just west of the house on the 850 ft. contour is 82 ft. deep, passing through scoria into bedrock.

Basaltic lava issued from the south-west corner and covers the country south and south-west as far as Bunker Hill. It is very vesicular in places. Some has visible phenocrysts of augite. Bores in the western valley show that it is about 110 ft. thick. Its surface is flat near the vent but develops crescentic ridges broadside on to the flow, which in one case becomes a broad flow standing about 20 ft. above the others. It finishes at Bunker Hill as a flow about 220 yds. wide with a pear-shaped end standing 25 ft. above the surrounding country. Its top is made up of rounded boulders and at Bunker Hill it shows disturbance in the shape of upturned blocks. Boulders are scattered on other parts of the lava field and the ends of flows are conspicuous. The low-lying parts are covered with soil and are waterlogged in winter.

Fairbank Vent

Fairbank Vent, 750 ft. above sea level, is due south of Crowes Hill and due west of Aitken's Hill. It is not described as a hill because the points of eruption, of which there are two, are now the edge of a plateau. The remains of one are visible as an eruption of brown olivine basalt, with a spatter and cellular scoria slope on the east side, on which there are a few pieces of ejected granodiorite. From the base there have been flows of iddingsitized olivine andesine basalts. The other is 100 ft. south, covered by a house. Part of a rough spatter cone can be seen which seems to have extruded a viscid iddingsitized olivine alkaline basalt over the western flanks and part of the northern flank of the first cone, making an almost flat plain that is almost level with the top of the cones. This rock weathers to give the appearance of brain coral and on broken surfaces looks as though made up of small globules. The flows on the plateau were probably of the aa type as the soil is full of small stones which have decomposed into a deep loamy light-coloured soil.

Granodiorite outcrops about 20 chains south of the vents and confines the lava from them. About 30 chains south-east of the vents a shallow well disclosed granodiorite under the lava.

Aitken's Hill

Aitken's Hill is about 2 miles south-east of Yuroke. It is 874 ft. above sea level and its base is about 30 chains in diameter. The vent is on a ridge and near the junction of Silurian bedrock and granodiorite, which it has covered with a hill of accumulation. The granodiorite is 700 ft. above sea level just south of the vent, the base of which is lower than the granodiorite. The cone is composite and built up of scoria on the east side, of lava flows and scoria on the north and south sides, and of lava on the west. The summit is a blunt V-shaped and dyke-like plug, one leg of the V pointing to Fairbank vent and the other to Crowes Hill. The outer edge forms a wall with serrated top, up to 6 ft. in width and 8 ft. in height. The inside of the V is lava, which is a somewhat alkaline iddingsitized olivine basalt, and the blunt point seems to be the point of extrusion of a flow of mauve lava which extends down the west side for about 20 chains. On the north-west side, 160 yds. from this point, there is another dyke-like plug from which lava has flowed to the north and north-west until it reached Aitken's Creek.

The earliest flows seem to have been of basalt, some of which has visible phenocrysts of augite. The flows filled a valley on the west, where a bore showed a depth of 120 ft. to granodiorite, and south-east of the bedrock and granodiorite ridge, in this case the flow coming from the west side around the south of the vent. The lava was evidently not very fluid as there are no tumuli on it and it is covered by a fair depth of soil containing small stones. It stands above the plain and was probably aa or scoriaceous. It extends to Broadmeadows, where the ends of the flows are conspicuous, and narrow flows follow valleys into Coburg.

The lava fields are shown as No. 6A on the map but their age in relation to the others could not be fixed. They are later than those of Crowes Hill and probably about contemporaneous with or somewhat earlier than those of Hayes Hill (No. 6).

A basaltic spatter and scoria cone formed about the vent during the basalt flows and its outer layers seem to have oxidized to a bright red and consolidated before the alkaline basalt plug was intruded through it because some of the beds on the south side show fractured and upturned edges. Nearby are thin flows of vesicular lava which appear to have flowed down the cone at about the same time. The plug seems to have been extruded in a semi-solid condition, the top 8 or 9 ft. being finely vesicular but the lower part non-vesicular. It seems as if a considerable part was extruded as many blocks lie about the cone on the outer side. There was evidently a liquid portion of the plug inside the V as a few pieces of granodiorite and large quantities of cellular lava, bombs, including breadcrust bombs, blocks of brown lava with ropy top still preserved, and a large amount of bright red scoria, probably part of the basaltic cone, were ejected. Under the straight portion of the cone is a bulbous portion which seems to have distended the cone and forced the straight portion up.

On the west side, about 50 chains from Aitken's Hill, there is now a deep narrow valley, and half a mile on the south-east side is a shallower flat-bottomed valley. Both have been eroded in basalt by the headwaters of the Moonee Ponds Creek which is older and more mature than Merri Creek.

Tulloch Hill

Tulloch Hill, 950 ft. above sea level, is about a quarter of a mile west of the junction of Seventeen Mile Lane and Old Sydney Road, Mickleham. Tulloch Hill, Crowes Hill and Fairbank Vent lie on an almost north-south line. There is little ejected material and the lava slopes away from the vent on all sides. The summit has a slope of 5° and is made up of short flows, some of the rock of which is salmon

coloured. The final flow is olivine basalt with visible phenocrysts of augite. The lava does not appear to have been very fluid as there are no tumuli upon it. The hill of accumulation rests on Silurian sandstone. A bore about 146 yds. east of the vent and another 50 yds. north of it disclosed a thickness of 173 ft. of lava. About 30 chains farther north the thickness is 65 ft., all three bores being on the 900 ft. contour. This vent was active after Mount Ridley and Crowes Hill as its lava overlies that from these vents. Patterson's Creek flows along the junction of Mount Ridley and Tulloch Hill lava. On the east side of Deep Creek valley Crowes Hill lava is almost entirely covered and normal iddingsitized olivine basalt from Tulloch Hill is exposed as the ends of infilled valleys.

Hayes Hill

Hayes Hill is not quite 2 miles east of Donnybrook railway station. It has a pear-shaped base about 30 chains north to south and about 20 chains east to west. It is 900 ft. above sea level at its highest point, the north end, which seems to be above the point of eruption. There is no crater, the north, east and west sides being composed to red vesicular scoria capped with spatter and ejected blocks. The north side has a slope of 15°. On the south side, on which there seems to be no scoria, lava flows extend from the top of the cone, falling at a steady slope of about 6° near the hill to form the plains.

The top flow, an alkaline limburgitic basalt, flowed south for about 30 chains. A bore about 20 chains south-east of the vent disclosed loose scoria under a thin cap of basalt. Another, about 50 chains west, penetrated 175 ft. of basalt before it was discontinued, probably having another 10 ft. of basalt beneath it. A bore on the south-east side on the 775 ft. contour penetrated 160 ft. of basalt, indicating a level of 590 ft. for the bedrock, giving a height of 330 ft. for the cone above bedrock.

It is impossible to say if lava from Bald Hill is buried under Hayes Hill but the author thinks it may be represented by a depression between Hayes Hill and Mount Frazer lavas. The lava from Hayes Hill filled the country to the east and south and occupies the valleys of the Plenty River and Darebin Creek. It reached the present site of Melbourne and from comparison with recent flows on the island of Hawaii it would have been flowing for about eight months. It still shows some of the more prominent features of the flows. Near the vent it is fairly level for about half a mile where a rather rough area of vesicular lava standing up 10 ft. occurs, apparently caused by a break in the conduit. About half a mile farther south the country has transverse concentric ridges.

The author considers that nearly all this basaltic lava was extruded at one time. The extent of the field is not extraordinary. Excluding the Plenty River basalt it is roughly 3½ miles broad but widens to about 6 miles near South Morang where it is joined by the tongue from the Plenty River valley. It contracts to less than 3 miles near Keon Park from where it extends down narrow valleys for 11 miles to the Melbourne district. The lava seems to have been pushed forward as a series of broad flows, which can be traced on the surface and slope away from the vent to the east, west and south. The surface is covered with pressure ridges and tumuli, most of them in a south-easterly direction which corresponds with the deepest bores. The surface within the mapped area has a fair amount of soil on it but the ridges are covered with medium-sized boulders, most of which are very vesicular. There is nothing to indicate what type of surfaces the flows had but from their general nature it was probably pahoehoe (ropy).

Mount Frazer

Mount Frazer, also known as Mount Bland or Beveridge Hill, is at Beveridge on the Hume Highway, 24 miles from Melbourne. Its appearance suggests its being a breached scoria cone with an angle of 15° on the north side and 10° on the east and west. On the south it descends in steps from the 1,100 to the 950 ft. contour. It rests on the eastern edge of the old middle interfluve, bedrock outcropping at 1,050 ft. above sea level on its north-western margin, giving 350 ft. as the height of its highest point above bedrock. The base on which it rests is about 1½ miles in diameter, rising on an easy grade from about 950 ft. to 1,150 ft.

It consists of a hill at the north-west end 1,350 ft. above sea level, about 15 chains wide and 20 long to the middle of the saddle which connects it to the next peak to the south-east, which is 1,400 ft. above sea level, 20 chains wide and 40 long. From this peak a narrow ridge, 1,200 ft. above sea level, extends S30°W for about 20 chains, then changes to the north-west for about 20 chains, ending in a peak 1,220 ft. above sea level.

On the west side Mount Frazer has a breach 150 yds. wide in front of which is a slope of about 15°. The breach broadens into a crater-like passage with a depression in the centre. There is a bank about 15 ft. high and then what appears to be a circular crater with a flat muddy bottom, 220 yds. in diameter and at an elevation of 1,150 ft. The sides have the angle of rest of scoria.

The scoria is unstratified and consists of vitric ash, lapilli, cinders, ejected bombs up to a foot in size, and a few blocks of finely vesicular basalt, all of it being "fire fountain" material as described by Stearns and Macdonald[2]. The fine material is unconsolidated and partly decomposed, under a consolidated coating of deep red scoria. The bombs contain inclusions of sedimentary rock, quartz, or olivine in all sizes up to about an inch. Sedimentary rock and olivine are also mixed with the scoria. Similar scoria occurs on the north side but on the east and south bombs predominate and there is much spatter on the peaks.

The author does not consider that the mountain is a breached cone or that the apparent crater, of which much of the roundness and flatness is caused by water action, is a true crater. It is thought that the sides are overlapping scoria cones of which the 1,400 ft. cone is the oldest. This overlies another cone or has had a landslide into the crater. The 1,350 ft. cone overlies it on the west side and whatever craters there may have been are just below the peaks on the north side. The 1,200 ft. ridge is a cone from which lava issued. The 1,220 ft. cone on the south side of the breach has a spatter top and overlies the ridge cone. The bank across the entrance to the false crater is a lava flow from this cone and there is also a small flow which issued from about 20 ft. up its side and flowed into the crater. The rock from this is a partly iddingsitized olivine basalt.

From the flanks of the various cones the points at which various lava flows issued can be seen and there may be some lava in the crater from flows. In front of the break where scoria would be expected there is none and what lava there is issued from under the scoria cones on each side. Ther may, in fact, be Silurian bedrock in front of the breach.

There are six small scoria cones, marked A to F in the map, at various places outside the above large ones. Some of them can be aligned with other points of eruption in the area, suggesting that they are located on lines of weakness in the bedrock. Cone A occurs 330 yds. west of the Hume Highway at the end of the north side of the breach. It consists of vesicular scoria and there appears to have been a lava flow from it, the cone being partly covered on the east with lava. It

lines up with the two southernmost of the large cones and Cone B, a much fresher-looking cone south-east of them, behind a house that is 330 yds. north of the junction of Station Road and Spring Street. Cone C, lying near the bottom of the bedrock slope on the south-east corner of Hume Highway and Station Road, is relatively large, and there issued from it a lava flow, the rock of which contains visible augite phenocrysts. Road cuttings on its north and east flanks expose unstratified scoria and bombs. It roughly lines up with the two western of the large cones and Green Hill. Cone D lies about 30 chains east and 10 north from this corner. Between D and C there is a flow from the southern flank of the main group of cones, which issued at about the same level as the flows inside the crater, and which extended to Lithgow Street. Cone E is at the north-west corner of Arrowsmith and Spring Streets. It is almost obliterated by lava. Along the east side of the cone from Station Road to Lithgow Street is an area of deep light soil suggesting the presence of Silurian bedrock but as there are no outcrops it has not been mapped as such. Cone F is half a mile north of Station Road in line with Spring Street. It differs from the others in that it has large blocks of extremely fine-grained glassy olivine basalt scattered about, having the appearance of a dyke rock. A bore located midway between Cones F and B went through 5 ft. of clay, 28 ft. of rough scoria, 28 ft. of lapilli and ash, 43 ft. of rough scoria, and 37 ft. of basalt. Cones E, B and F are in alignment.

To test the idea that Mount Frazer is not a breached cone the author carried out some experiments to find the figure which would result by pouring mounds to scale in the order worked out from field observations on to a ground plan of the vents. Sugar was used to secure the angle of rest and the result was a close copy of Mount Frazer.

The flows from Mount Frazer were mostly thick and sluggish, with slightly undulating surfaces with little debris on them. Their ends are visible on the plains and here and there are tumuli, the largest of which is Hill 60, $1\frac{1}{4}$ miles south-east of Beveridge railway station. Viewed from Woodstock it is prominent but it is merely a pressure dome on the end of a flow and rising 20 ft. above it.

The final big flow spread three-quarters of the way across the eastern valley and has an abrupt side standing 15 to 20 ft. above the underlying flows. Opposite Bald Hill it piled up on lava from Hayes Hill and probably also from Bald Hill. Where it encountered the underlying lava it developed crescent-shaped ridges facing broadside on to the flow and there is often a pressure ridge on the terminal points. The lava went around the west side of Hayes Hill where it has numerous crescentic ridges some of which develop into tumuli. It has short extensions from the sides, not shown on the map, and a prominent mound just south-west of Hayes Hill is just behind the end of such an extension and due to liquid pressure. It continued as a flow about a mile wide with an abrupt eastern edge and a high ridge on the western side, where the top is slightly undulating. It is virtually free of boulders except on some of the crescentic tumuli. It ends at the junction of Merri Creek and Lime Creek due east of the 12 mile post on the Hume Highway, as a tumbled heap of massive blocks with sides up to 6 ft. caused by the undermining by the streams. Here there is an exposure of a much older vesicular ropy basalt overlain by a pebble bed of bedrock detritus and lava which was later covered by the Mount Frazer lava.

Springs Hill

Springs Hill on the west side of the Hume Highway north of Mount Frazer was probably the last vent in the district to be active. Its highest point is 1,200 ft. above sea level. It is a basaltic cone with a roughly circular base one mile in diameter,

made up of numerous thick and thin flows of pahoehoe lava. The tops of the flows are rough and vesicular and extend to short distances from the vent, giving a terraced appearance on the west and north-west sides. Upon them may be seen loose blocks which enclose scoria and small boulders which are the equivalent of accretionary lava balls. There are also up-ended slabs that have been pushed along by other flows and show that some flows were only 12 to 18 inches thick. Upon the flows may be seen a few small gas blowholes. There is a small amount of lithic scoria around the vents but the whole hill gives the impression of quiet extrusion of cool lava that had lost most of its gases.

The bigger flows are up to 20 ft. thick and $1\frac{1}{4}$ miles in length and usually have a broad bull nose. They overlie Mount Frazer lava on the south and south-east and Green Hill lava on the north-east. They overlie Silurian bedrock and are overlain by alluvium on the north-west where they form a ridge which has blocked the drainage on the west side.

The top of the hill has a semi-circular ridge about 333 yds. in diameter around its north side which is made up of five small cones, its base being about 50 ft. thick. These cones have lip flows. The central cone is the highest, has a slope of 15° and is made up of lava flows and scoria with large blocks of vesicular lava on the peak. From the summit to the base there is a narrow thin flow of limburgitic andesine basalt. The lava from the other vents is olivine basalt rich in labradorite. The eastern cone stands on a base about 1,150 ft. above sea level and is about 15 ft. in height. The western end of the ridge is about 10 ft. lower than the central cone and is composed of large vesicular blocks. From it there issued a thick pahoehoe flow of vesicular lava which flowed south, the top of which is covered by boulders. The skin of pahoehoe is glassy and in recent flows the glassy skins of the tubes show as veins in the tops of the flows. In older flows such as those described these veins and skins weather first giving rise to boulders and wide irregular joints.

A flat semi-circular area on top of the hill covered with soil is shown on the map as partly Silurian bedrock because the soil contains much fine quartz silt. Bedrock mapped near the Hume Highway is identified on the same evidence.

Quartz Inclusions in Basalt

Inclusions of quartz occur in lava flows from many of the vents. A striking example occurs at Bunker's Hill in what appears to be the end of a basalt flow from Bald Hill which crosses the Hume Highway $18\frac{1}{2}$ miles from Melbourne. The inclusions of milky quartz are angular and of all sizes down from roughly cubic pieces seven inches across. With them are a few pieces of grey silicified sandstone and the common yellow fine-grained sandstone, some of which show signs of solution in the lava. When fractured the quartz has a lustreless porcellanous appearance. The pieces have innumerable cracks, some of which have basalt squeezed into them. The quartz shows signs of secondary silification and the basalt immediately surrounding it has rows of fine vesicles. The lava is moderately vesicular and many of the vesicles have secondary deposits around them. The inclusions seem to be almost confined to an upper and a lower limit.

The milky quartz seems to be derived from quartz veins within the Silurian bedrock and to have been ejected with the lava from the vent.

Mr. A. J. Gaskin sectioned some of this quartz and states "that the thin section showed that the material was still almost pure quartz, but the grain was so shattered that it was not possible to determine what the strucure migh have been, the shatter effect being caused by thermal expansion and contraction coupled with volume changes accompanying the 573°C. inversion. There are signs of isotropic material

in some of the shatter cracks together with minute wedge-shaped birefringent crystals. The transformation to tridymite or cristobalite begins at 870° and the rate is extremely slow up to 1000° unless mineralizers are present. With a short heating and no mineralizers the material could have reached 1,450° but the most likely lower limit of heating is 1,000°."

The author immersed fresh quartz from the district in cast iron at 1,400°C. Whether hot or cold it powdered and would only carry in a lava flow as very fine fragments. A 3 in. cube of quartz was then placed two-thirds the way down in a 2 ft. x 2 ft. slag container and slag at 1,400° poured around it. The cube took about six hours to cool and was difficult to recover, but the quartz looked much the same as that in the lava. The slag resembles and behaves much the same as basalt. This suggests that quartz picked up by the lava at 1,100° or 1,200° C. would finish in the state in which it is found in the cooled rock.

Similar inclusions of quartz occur in a cutting near "Warlaby" on Konagaderra Road, together with sandstone; on Fifteen Mile Lane between Craigieburn and Woodstock; in a cutting on the Woodstock Road three-quarters of a mile north of Woodstock and on the Donnybrook-Woodstock Road one mile east of the railway station; in a quarry on the north-west of Springs Hill and, as small pieces, in the bombs from Mount Frazer. It has been recorded from other places in Victoria by Fenner,[3] Grayson and Mahony,[4] Skeats and James[5] and Coulson[6].

Conclusions

The field evidence indicates a succession of eruptions and outpourings of lava from the Lower Pliocene or earlier to the Upper Pleistocene. Pretty Sally Hill and a vent north of Kilmore compare in degree of erosion and decomposition of their lava with the Greensborough Older Basalt. Springs Hill, where the steep central cone is mainly stony scoria with large blocks on the top and a dribble of limburgitic basalt down one side, is hardly touched by erosion and is probably Upper Pleistocene. Green Hill is an eroded rounded dome covered with a mantle of soil whose lava flows had a deep black soil on them before they were covered with alluvium. It was formed later than Pretty Sally Hill as it fills a valley that was eroded on the margin of the latter. It appears to have been in much the same condition as to-day by the time Mount Frazer erupted and caused its soil and lava flows to be covered with alluvium. By comparison with Springs Hill it is probably Upper Pliocene. Mount Frazer has a light mantle of red-brown soil and on the flatter part the tuff has decomposed to a fine yellow clay with a loamy soil on it. Mount Frazer lava is overlain by Springs Hill lava on its north-west corner and overlies Hayes Hill lava on the Donnybrook-Woodstock road. Hayes Hill is probably Lower Pleistocene as the point of eruption has suffered some erosion and is covered with a fair amount of black soil. Its lava flows are covered with deep soil in parts and it is covered with a good growth of trees. Bald Hill is overlain by lava from Mount Frazer. It is covered with a deep mantle of black or red soil. It seems to have erupted after a dormant interval and to have poured basaltic lava on its south-west side before flows issued from the north vent of Mount Ridley and Mount Frazer. The general erosion of the dome is much greater than that of Hayes Hill. It was probably active from Upper Pliocene to Lower Pleistocene. The south vent of Mount Ridley is thought to be Upper Pliocene as it is overlain by other flows but does not overlie any. Its flows are covered by a deep buff-coloured loamy soil containing buckshot gravel. This soil and the flows look similar to flows in Western Victoria that are considered to be Pliocene. Crowes Hill is considered to be about the same age as Mount Ridley but there is no definite evidence bearing on their relative ages. The

flows from Crowes Hill have a deep soil of light colour containing buckshot gravel and are much eroded on the Deep Creek side. Tulloch Hill is younger than Mount Ridley and Crowes Hill, as shown by exposures on Patterson's Creek, but its lava is overlain by that from Mount Frazer and its age is thought to be about the same as that of Hayes Hill. Aitken's Hill and Fairbank Vent are thought to be older than Mount Frazer, mainly on the evidence of the depth of soil on the respective lavas.

The points of eruption could be said to resemble the Phlegrean Fields in Southern Italy as they are from 1½ to 3½ miles apart and some look as if they were active only once or twice. Others are double vents. It is possible to line up certain vents such as:

(1) Hayes Hill, Vent F of Mount Frazer, Pretty Sally Hill and a vent three miles beyond it in a direction N10°W;
(2) Green Hill, Mount Frazer, Bald Hill;
(3) Green Hill, Springs Hill, Vent A of Mount Frazer and the two vents of Mount Ridley;
(4) Tulloch Hill, the south vent of Mount Ridley and a dyke three-quarters of a mile to the east lie in an almost east-west line which to the west coincides with a westerly-trending section of Deep Creek and to the east passes through a basalt-filled gap between Woody Hill and Summer Hill and also through the Mernda Gap;
(5) the two vents of Crowes Hill and Aitken's Hill;
(6) Fairbank Vent, Crowes Hill and Tulloch Hill.

It is notable that the big vents, Mount Frazer, Crowes Hill and Mount Ridley, are at intersections of lines.

The lava of the extensive flows which filled the valleys is olivine basalt. Olivine is visible in some flows north of Mount Ridley and certain flows south-west of Mount Ridley contain visible phenocrysts of augite. The vents themselves can be divided into two provinces, those that were active at a very early period and whose end-product was alkali basalt, and those whose end-product was limburgitic basalt or limburgite. The alkali basalts are all grouped on or near the granodiorite, though Tulloch Hill produced only olivine basalt with visible phenocrysts of augite. The limburgites are on and north of Mount Ridley and have been extruded after big flows of olivine basalt, usually on one side of the basaltic vent. It is likely that both the alkali basalts and limburgitic lavas are derivatives of olivine basalt, the alkali basalts being the products of a residual fluid that has been driven out of the almost fully crystallized magma by gas in the manner suggested by Shand,[7] the limburgite being the result of crystal settling.

Acknowledgements

I am indebted to Mr. C. Dennet and Mr. Neil Smith who allowed me to use their bore logs; to Dr. C. M. Tattam for the descriptive petrology except that of Mount Frazer which was done by Dr. A. B. Edwards; to Mr. A. J. Gaskin for information on inclusions of quartz in basalt; to Mr. A. Coulson and Mr. E. D. Gill for help and advice; and to Mr. Keith Miller for redrawing the map.

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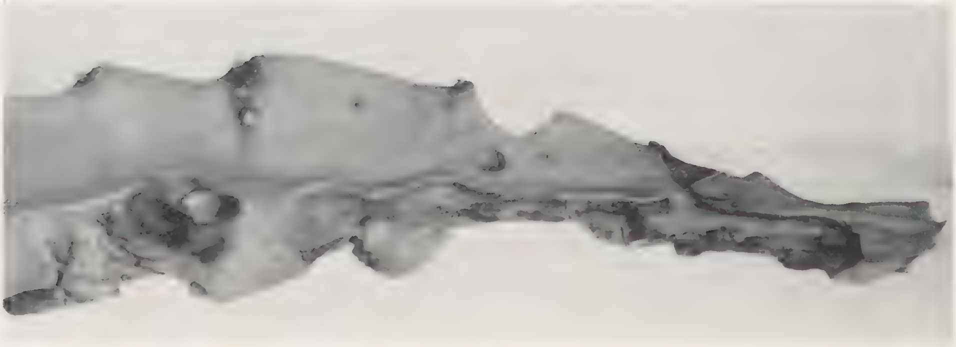

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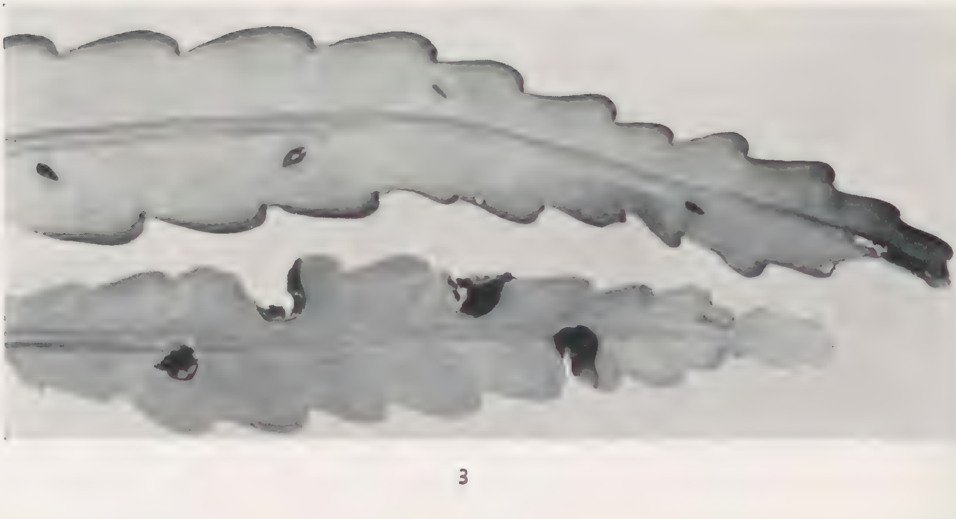

3

2

CACTUS CANKER CAUSED BY BOTRYTIS CINEREA PERS.

By Eileen E. Fisher

[Read 10 June 1954]

Epiphyllum crenatum, which is one of the commonest Cactus varieties grown in Victoria, usually remains remarkably free from disease. In November, 1953, however, a plant grown at Orbost, in south-eastern Victoria, was submitted to the Plant Research Laboratory, Burnley, for disease diagnosis.

The symptoms comprised "soft rot" of flower buds and phylloclades. Later, the phylloclade infection developed into a severe form of cankering, which was the most conspicuous feature of the disease. (Pl. I, fig. 1).

Botrytis cinerea was isolated from both flower buds and phylloclade lesions and the pathogenicity of these isolates was confirmed by the inoculation of detached phylloclades.

In these pathogenicity tests, the fungal hyphae were inserted into four incisions, approximately 0·5 cm. in length, made in the tissue of the phylloclade, on either side of the midrib. Both inoculated and control specimens were then placed in closed polythene bags and kept at room temperature.

Three days later, circular-elliptical "Chestnut-Brown" Ridgway[3] (Pl. 14) soft-rotted areas, approximately 1 cm. diameter, appeared at the site of the inoculation. On the fourth day after inoculation, a clearly defined but undifferentiated barrier appeared at a distance of $\frac{1}{4}$-$\frac{1}{2}$ cm. beyond the margin of rotted tissue. (Pl. I, fig. 2.) After 18 days, the rot extended as far as this barrier, which eventually became suberized and differentiated to form cork. When the rotted tissue finally dried out, a typical canker was formed. (Pl. I, fig. 3.)

In Europe, *B. cinerea* has been found to cause "stem rot" and "watery rot" in various genera of the *Cactaceae* (see References 1, 2, 4 and 5), but *Epiphyllum crenatum* has not been recorded as a host. Furthermore, this is the first time that *B. cinerea* has been found to cause "canker" in the *Cactaceae*.

There is no previous record of *B. cinerea* infecting any species of the *Cactaceae* in Australia.

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Explanation of Plate I

Illustrating disease symptoms of *Epiphyllum crenatum*, infected with *Botrytis cinerea*.

Fig. 1.—Natural infection of phylloclade. $\frac{3}{4}$ natural size.

Fig. 2.—Artificial infection of phylloclade, 4 days after inoculation. 2/5 natural size. Top, control. Below, inoculated specimen.

Fig. 3.—Artificial infection of phylloclade, two months after inoculation. 1/3 natural size. Top, control. Below, inoculated specimen.

The photographs were taken by Mr. C. Richardson and Miss C. Guest.

3

THE GEOLOGY OF THE DEDDICK–WULGULMERANG AREA, EAST GIPPSLAND

By A. E. RINGWOOD, M.Sc.

[Read 10 June, 1954]

Abstract

The Snowy River Volcanics of Lower Devonian age consisting mainly of rhyodacites together with smaller amounts of pyroclastics and latites rest unconformably upon a basement of folded Upper Ordovician sediments intruded by granodiorite. In the western portion of the area, the volcanics reach a thickness of over 10,000 feet and are folded into a large syncline striking north-south. The extrusion of the rhyodacites is closely connected with an extensive arcuate fracture. Subsidence of the basement rock has occurred south of the fracture simultaneously with extrusion of rhyodacites, resulting in the accumulation of great thicknesses of rhyodacites and pyroclastics in the depression made by the downthrown block.

Epi Middle Devonian lamprophyre dykes intrude the granodiorite and also the rhyodacites. Mineralization resulting in the formation of galena deposits occurs in the downthrown block of the granodiorite close to the main fracture, and is closely associated with the lamprophyre dykes which are parallel to the main fracture.

Table of Contents

Introduction

An area of about 18 by 10 miles covering portions of the parishes of Woongulmerang East, Woongulmerang West, Deddick and Chilpin is dealt with in this paper. Because of the rugged and inaccessible nature of the terrain some of the mapping is best classed as reconnaissance. However, key areas along both sides of the granodiorite-rhyodacite contacts in the central part of the area, together with most of the Wulgulmerang plateau, have been mapped in more detail. Reconnaissance mapping has been carried out mainly in the eastern and western extremities of the region and has been limited mainly to delineating the three major flows of rhyodacite. Mapping of this kind is indicated by broken lines, more accurate mapping by full lines.

Previous Work

The only important contributions to the geology of this area have been made by Howitt (1876, 1878) and Ferguson (1899). Howitt made a traverse down part of the Little River Gorge. He came to the conclusion that the contact of granodiorite and rhyodacite at Little River was a fault of considerable displacement, extending through to Suggan Buggan. He subdivided the "Snowy River Porphyries" into a basal series of massive quartz porphyries and felsites and an upper series of fragmentary rocks, mainly tuffs and agglomerates.

In 1899 Ferguson published his report on the geology of the Mt. Deddick silver-lead field, together with a map. This report dealt principally with the mining geology of the area, and only briefly with the general geology. However, Ferguson recognized most of the major features of the general geology. He differed from Howitt regarding the existence of a fault at the rhyodacite-granodiorite contact on the Little River.

Jenkins (1899), Sterling (1899), Dunn (1909) and Whitelaw (1921) have contributed short reports mainly on the galena deposits, but they have added little to the work of Howitt and Ferguson. Reports on neighbouring districts which have some bearing upon the area in question have been published by Crohn (1949) for the Omeo District, Teale (1920), Cochrane and Samson (1947) for the Nowa Nowa-South Buchan district, and Gaskin (1943) for Bindi. Gaskin has also mapped the Buchan area, but has not yet published his results.

Physiography

The major feature of the physiography of the area is the youthful dissection of an elevated peneplain by the Snowy River and its tributaries. The peneplain lies at a height of about 2,500-3,000 ft. and slopes gently towards the south. On the west side of the Snowy River in the Wulgulmerang area, much of the peneplain is covered by basalt. On physiographical grounds, Hills (1938) has suggested that this basalt belongs to the Newer Basalt Series, and consequently the uplift and subsequent

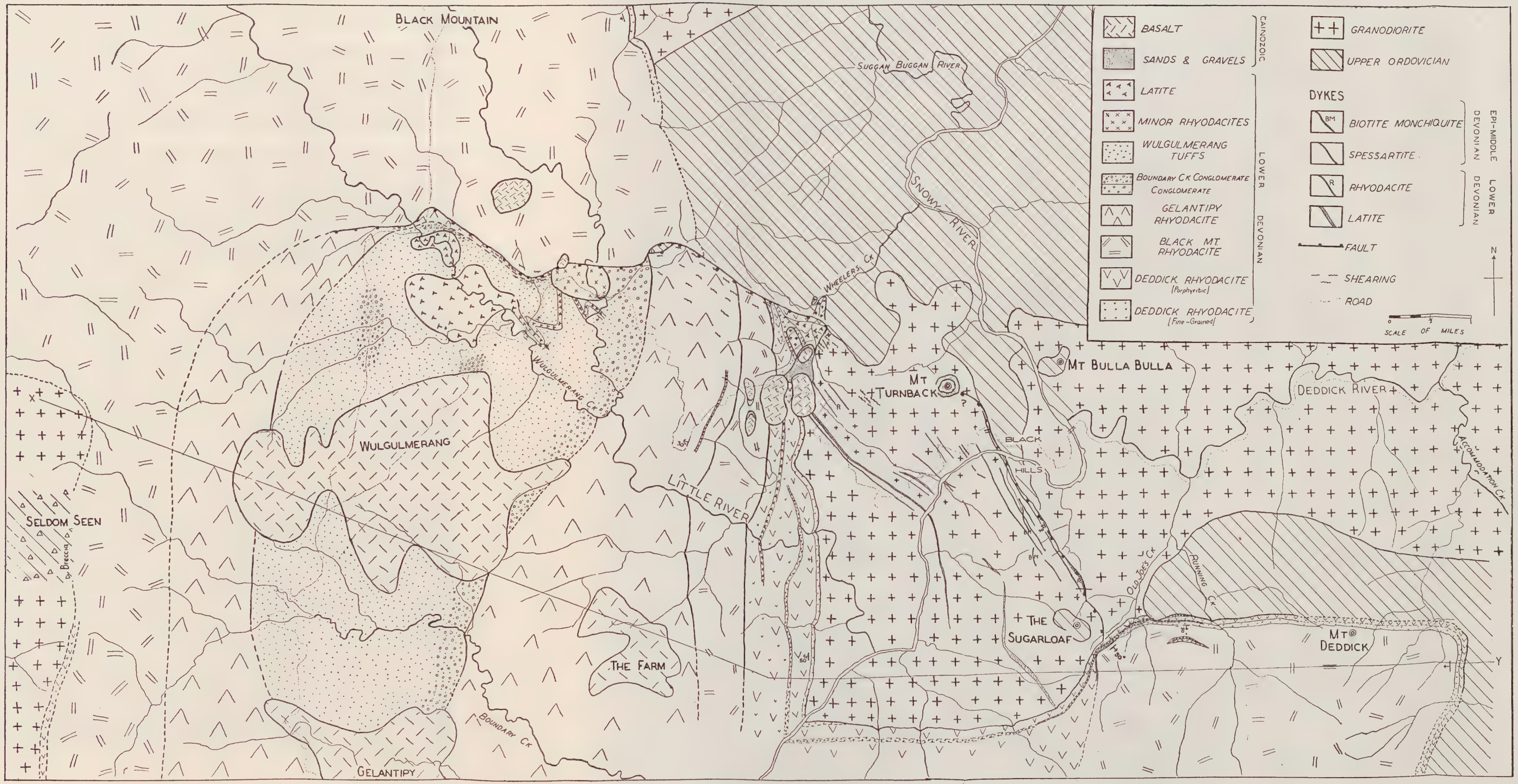

BLACK MOUNTAIN
SUGGAN BUGGAN RIVER
SNOWY RIVER
WHEELERS CK
WULGULMERANG CK
WULGULMERANG
LITTLE RIVER
MT TURNBACK
MT BULLA BULLA
DEDDICK RIVER
BLACK HILLS
ACCOMMODATION CK
OLD JOES CK
RUNNING CK
THE SUGARLOAF
MT DEDDICK
SELDOM SEEN
Breccia
THE FARM
BOUNDARY CK
GELANTIPY
X
Y
BASALT
SANDS & GRAVELS
CAINOZOIC
LATITE
MINOR RHYODACITES
WULGULMERANG TUFFS
BOUNDARY CK CONGLOMERATE CONGLOMERATE
GELANTIPY RHYODACITE
BLACK MT RHYODACITE
DEDDICK RHYODACITE (Porphyritic)
DEDDICK RHYODACITE (Fine-Grained)
LOWER DEVONIAN
GRANODIORITE
UPPER ORDOVICIAN
DYKES
BIOTITE MONCHIQUITE
SPESSARTITE
EPI-MIDDLE DEVONIAN
RHYODACITE
LATITE
LOWER DEVONIAN
FAULT
SHEARING
ROAD
N
SCALE OF MILES

Fig. 1

erosion of the peneplain has occurred since the extrusion of Newer Basalt. In a relatively short time steep-sided valleys and gorges have been gouged out by the Snowy River, Little River, Boundary Creek, Wheelers Creek, Suggan Buggan River, Running Creek and smaller tributaries.

The topography is extremely youthful, and is largely controlled by differential erosion of granodiorite, rhyodacites and Ordovician sediments. The dissection of rhyodacites and slates has resulted in a topography extremely rugged and precipitous, possessing great scenic grandeur. The Little River, one of the principal tributaries, has cut a gorge 2,500 ft. deep, often with sheer walls. This stream falls 2,000 ft. in a distance of one mile. Wulgulmerang Creek drops into the Little River over a waterfall 1,000 ft. high.

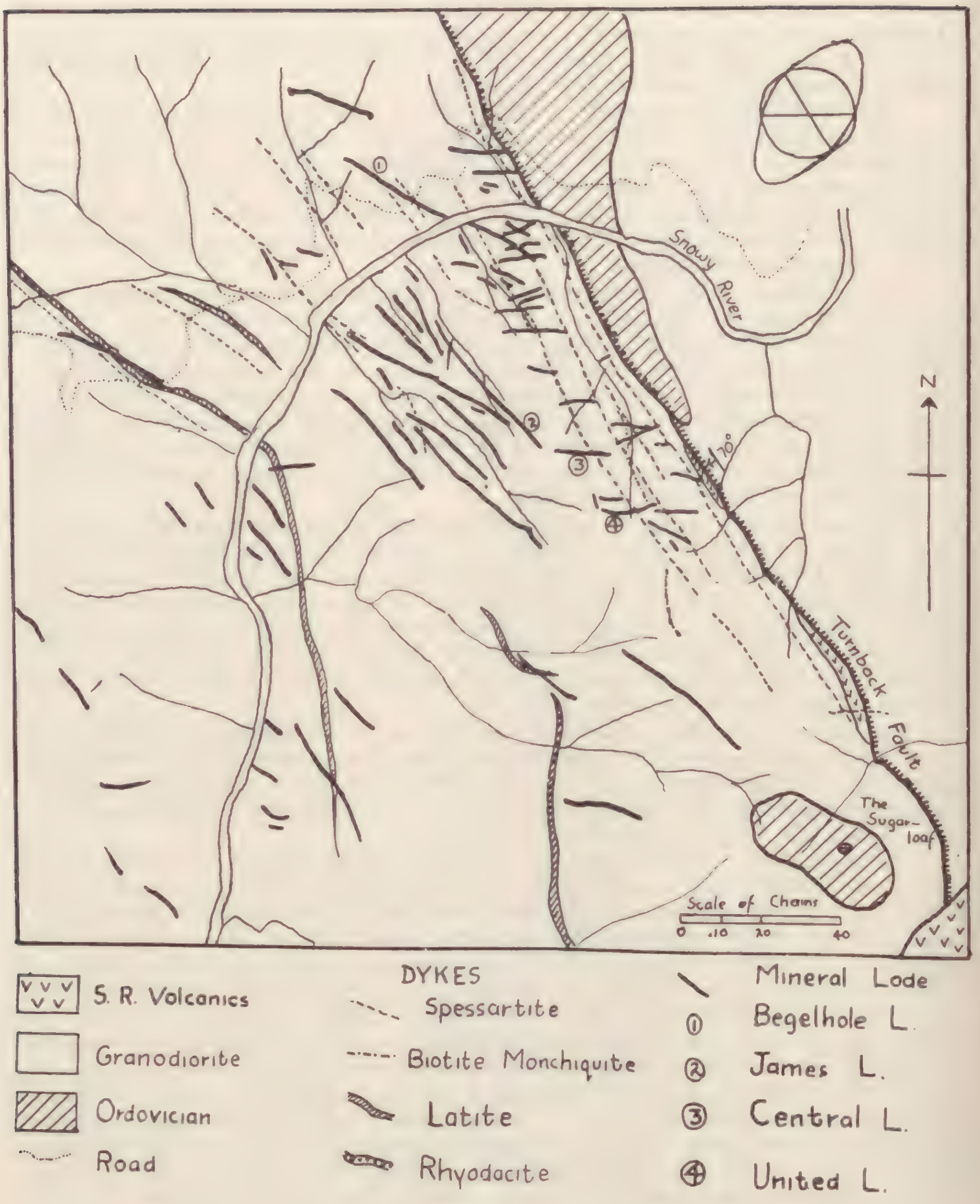
The behaviour of rhyodacite and slate country during dissection has been very similar, although the rhyodacites tend to form more precipitous gorges. This is doubtless due to the strong jointing existing in the rhyodacites. In general, granodiorite is much more easily eroded than the rhyodacite and Ordovician, and therefore tends to occupy large topographic depressions as at Deddick, and Suggan Buggan. Consequently it is usually possible to pick up the granodiorite boundaries accurately upon aerial photographs relying solely upon topography as a criterion. Plate II shows an aerial photograph taken at 17,000 ft. of the granodiorite-rhyodacite contact near the Little River at Deddick.

The control of drainage by geological structure is not very marked within the area. There are, however, some examples. Two miles below the bridge at McKellop's Crossing a long slender tongue of Ordovician rocks protrudes into the granodiorite, striking N.N.W. Parallel to and S.W. from this tongue there has been strong and persistent fracturing and faulting in the granodiorite. This is shown by the numerous lamprophyre dykes, mineral lodes, and intense jointing, which have the same strike. These persistent fractures appear to have determined the direction of the local stream valleys, which lie parallel (Fig. 2).

Another case in which geological structure may have influenced drainage lies near the Suggan Buggan River, due east of Black Mountain (Fig. 1). Here a very marked parallel drainage pattern in Ordovician slates and sandstones lies parallel to the main granodiorite Ordovician contact. It is probable that jointing parallel to the contact may be responsible for this pattern.

The pre-basaltic peneplain may be recognized on both sides of the Snowy River, and is remarkably even, especially on the plateau lying immediately south of Mt. Deddick. It is best developed in the Wulgulmerang-Black Mountain area where it is largely intact, the relatively small amount of dissection it had undergone being indicative of relatively recent uplift. It was this reason which led Hills (1938) to place the basalt lying on top of the peneplain among the Newer Basalt Series. In this area the basalts are quite thin, rarely of greater thickness than 100 ft. Farther south near Gelantipy the pre-basaltic peneplain had suffered much more dissection before the extrusion of the basalt. This is demonstrated by the rapid variations in thickness of the basalt which obviously rests upon a very uneven surface. Although the basalt in some places reaches a thickness of 500 ft., inliers of rhyodacite outcrop through the basalt quite close to the places of maximum thickness. This indicates that dissection of the pre-basaltic peneplain, although insignificant in the Wulgulmerang area, increased towards the south where it became quite marked.

The uplift of the peneplain, following extrusion of the basalt, probably occurred during the Lower Pliocene period (Hills, 1940). Although evidence of recent faulting is lacking, it seems likely that this district has also been elevated by the Kosciusko Uplift—the Snowy Mountains and Kosciusko Plateau can be regarded as a northern



Snowy River
Turnback Fault
70°
The Sugar-loaf
N
Scale of Chains
0 10 20 40
S. R. Volcanics
Granodiorite
Ordovician
Road
DYKES
Spessartite
Biotite Monchiquite
Latite
Rhyodacite
Mineral Lode
① Begelhole L.
② James L.
③ Central L.
④ United L.

FIG. 2

extension of the tilted peneplain of the Gelantipy, Wulgulmerang and Cobberas regions.

Several patches of basalt, often underlain by river gravels, occur at heights of about 2,000 ft. in the central part of the area—notably on Mt. Turnback, "The Farm", and the head of Wheelers Creek. These basalts are 1,000 ft. lower than those at Wulgulmerang, and appear to be residuals of a formerly more extensive flow. There is no evidence to suggest that they owe their position to faulting. They probably represent remnants of a separate flow of basalt which flowed down the valley of the Snowy River whilst that valley was in an early stage of dissection. This interpretation is supported by the fact that beds of river gravels are found underneath some of these patches. River gravels do not occur under the basalt at Wulgulmerang.

General Geology

Upper Ordovician

Sediments of Upper Ordovician age are widespread throughout the area. The largest exposures occur upstream from the bridge at McKellops Crossing on the Snowy River. Other patches occur on the Sugarloaf, at Mt. Deddick, and in the far west near Seldom Seen Lookout. The latter occurrence is not recorded in the 8 miles to the inch Geological Survey map of Victoria.

The sediments consist of sandstones, greywackes, mudstones, shales and slates, in places carbonaceous. These have been folded in an irregular manner, the strikes not being constant. Dips average 30° to 40°, but in places they are as low as 20°, and elsewhere vertical dips are to be found. The strikes also vary, such a wide variety was met with that it is impossible to say whether there is any preferred direction. Folding of this nature is unusual in Victorian Ordovician rocks. The apparent irregularity is largely due to the high angles of pitch encountered. Near Mt. Deddick these were sometimes as high as 35°.

Graptolites found by Ferguson (1899) in some of the slates in the Deddick district were determined by Hall. They are indicative of Upper Ordovician age. Graptolites of this age have also been found by Tonner in the Accommodation Creek area near the copper mine (Hall 1912) and also by Thomas (personal communication) some distance upstream from the copper mine. The graptolites include *Dicellograptus* sp., *climacograptus,* fragments of Diplograptidae, *Dicranograptus hians, Climacograptus caudatus, Cryptograptus tricornis, Diplograptus calcaratus.*

After folding, the sediments were intruded by a batholith of granodiorite. Much of the roof of the batholith has been removed by erosion, but part remains—the Sugarloaf, for example, represents a remnant of the roof. It consists of a cone of hard metamorphosed sediments resting upon the granodiorite at an elevation of 1,800 ft. Parts of Mt. Deddick and Mt. Bulla Bulla are also remnants of the roof of the batholith, which underlies them at a shallow depth. Metamorphism of the sediments by granodiorite has resulted in the formation mainly of quartzites and quartz sericite hornfels, near the contact.

The grade of metamorphism is fairly low. A slide, No. 7726, University of Melbourne Collection, has been taken across the contact at the Black Hills, on the Snowy River. It shows a mudstone which has been partially recrystallized. Numerous spots of chloritic material and iron ore have been developed, whilst much of the finer argillaceous constituents have been recrystallized to chlorite and sericite. The granodiorite at the contact has been chilled to a quartz porphyrite, the crystals of quartz, plagioclase and altered biotite are closely packed in a very fine-grained, almost glassy groundmass. Subsequent shearing has occurred, fracturing especially

the quartz phenocrysts. A banded shale, No. 7606, taken about 100 yards from the same contact, has been recrystallized into a quartz sericite hornfels. Spotting has developed in some of the bands. Although taken further from the contact, this specimen appears to have been more strongly metamorphosed than No. 7726 taken on the contact. This suggests that the initial composition of the rock, more especially its water content has been an important factor controlling the metamorphism.

Slide No. 7727 is taken from about 50 yards from the granodiorite-Ordovician contact near Mt. Deddick. The original rock was a sandstone. It has been changed to a quartzite with interlocking quartz grains. Subordinate iron ores and biotite have developed at the grain boundaries. A greywacke, No. 7608, from the Sugarloaf shows evidence of stronger metamorphism, small crystals of muscovite and chlorite have been abundantly developed.

In most places the contact effects have been limited to the production of low to medium grade hornfels. However, in one area, about three-quarters of a mile north of the Sugarloaf, the contact effects have been of an entirely different nature. Here large and small blocks of Ordovician sediments ranging up to 100 yards across, lying close to the roof of the batholith, have been strongly felspathized, giving rise to a granitoid rock as an end product. The petrology of these rocks will be dealt with at a later stage.

Along the north side of the granodiorite-Ordovician contact at the Black Hills, the greywackes and quartzites have been strongly brecciated. The appearance of these breccias led Stirling (1899) to conclude that they marked the site of a great thrust fault and that the narrow tongue of Ordovician rocks had been thrust into its present position from the north. Ferguson did not support this view but considered the breccias to be the result of purely local crushing. The present work supports Ferguson's view. Ironically enough, one side of this narrow tongue has been faulted, but it is the opposite side to the brecciated zone. On the brecciated side a sharp contact between granodiorite and hornfels occurs (section 7726).

Microscopic examination of these breccias (Nos. 7609, 7610) shows that the hornfels is traversed by innumerable minute fractures which break up the rock into small fragments. However, there has been little movement along these fractures—the fragments have remained essentially in place. It is clear, therefore, that this is not, as Stirling thought, a fault breccia, but would be better termed a crush breccia. Similar rocks have been found interbedded with the Snowy River Volcanics. Thin bands of sediments have been overlain by rhyodacite which has metamorphosed them somewhat, rendering them brittle and hard. Subsequently, the rhyodacites were folded. The resultant interformational stress on the incompetent sediments has given rise to crush breccias exactly the same as those which occur at the granodiorite hornfels contact at the Black Hills.

The breccias at the Black Hills were formed in the same way. Metamorphism of the sediments by granodiorite rendered them brittle. Subsequent regional stress has caused crushing at the contact without faulting, resulting in the formation of multitudinous small fractures, giving rise to a breccia. The granodiorite on the other side of the tongue has yielded by extensive shearing and hence breccias have not been developed. However, this aspect will be enlarged upon subsequently.

Weathering of these rocks has been controlled by the innumerable fractures, and hence each individual fragment is made to stand out in strong relief on a weathered surface, emphasizing the brecciated structure (hand specimens A6, A7, University of Melbourne Collection). It is noteworthy that brecciation of this type occurs only in metamorphosed sandstones and greywackes, and not in metamorphosed slates, shales and mudstones.

Silurian

Granodiorite

A large area of granodiorite occurs in the Deddick district, centred around the junction of the Deddick and Snowy Rivers, and extending eastwards up the Deddick Valley. Granodiorite also occurs in the north around Suggan Buggan, and in the far west along the Buchan River. It is probable that these outcrops are all connected and that granitic rocks underlie considerable areas of the Snowy River Volcanics in the district. The granodiorites form the southern part of a large batholith which extends northwards into New South Wales past Mt. Kosciusko and Cooma. In the Deddick region all the land which is utilized is underlain by granodiorite. When cleared it supports a moderate growth of pasture, and much of the Deddick valley is used for grazing. No farming or grazing is done in the area occupied by rhyodacite, or Ordovician sediments around Deddick. However, on the Wulgulmerang Plateau, rhyodacite gives rise to good grazing country, as does the basalt.

In the Deddick area, there are all gradations present between granites and granodiorites. However, rocks ranging in composition from adamellite to true granodiorite appear to predominate. An interesting feature is the common presence of large amounts of cordierite both fresh and pinitised.

In general, the rocks consist of quartz, andesine ($Ab_{60}An_{40}$), orthoclase, microperthite, cordierite, abundant biotite and occasional apatite. In slide No. 7615 andesine occurs commonly in idiomorphic tabular crystals, frequently zoned. Sericitisation of the cores is very common. Smaller amounts of orthoclase and microperthite occur in approximately equal amounts. They tend to occur interstitially to the biotite and andesine. Anhedral crystals of quartz are abundant. They are frequently fractured and carry considerable amounts of small inclusions arranged in linear fashion. Biotite is abundant in euhedral crystals and is pleochroic from light yellow to dark brown, almost black, indicating lepidomelane. Crystals of apatite are frequently included in the biotite, some of which has suffered a considerable amount of secondary alteration to chlorite, and to a lesser extent, iron ore. Small rounded zircons and an occasional small crystal of sphene occur as accessories. Cordierite occurs as a few large rounded crystals up to 3 mm. in diameter. Inclusions of prismatic sillimanite are common. The cordierite also contains rounded inclusions of quartz and biotite crystals, and occasionally of felspar. Apparently it has crystallized at a relatively late stage. It is usually fairly fresh, showing only a small degree of alteration to chlorite and pinite, however some of the crystals have been completely altered to chlorite.

In contrast to the above section No. 7614 contains a large amount of microperthite, making the rock a true granite. The microperthite occurs as large poikilitic plates enclosing all the other minerals of the rock. This specimen has been slightly altered, resulting in partial sericitisation of andesine and the development of muscovite, mainly from biotite. The alteration may be due to its proximity to the rhyodacite contact at Little River, only 300 yards away. Cordierite is of common occurrence in this rock, too. One crystal measures 6 mm. across. It is only partly pinitised, and its mutual relations with other minerals are similar to those described in section 7615.

Slides Nos. 7628 and 7630 are essentially similar to those described above. However, they tend more towards adamellites in composition.

The late stage differentiates of the granodiorite consist predominantly of aplites, which are quite common. Pegmatites are absent. The aplites occur mainly as dykes occupying tension cracks formed in the granodiorite during cooling. The dykes are frozen to the walls of the granodiorite and do not occupy fault planes. In two places,

aplitic rocks occur in massive form—near the Little River contact, and about one mile along the spur leading north from the Sugarloaf. At the latter locality the aplites show all stages of gradation into masses and segregations of typical vein quartz. Hand specimens B 18, B 19.

The granodiorite has been intensely shattered by tectonic movements but has not developed any gneissic structures. Intense jointing and fracturing extend throughout the intrusion; it would be difficult in most places to obtain a 2 ft. cube of granodiorite without several fractures. Slickensides are extremely common, Usually they indicate horizontal movement. Offsetting of aplite dykes is also very common and illustrates well the relative movements of adjacent blocks. This intense shattering was probably caused by the tectonic movements which folded the Lower Devonian Rhyodacite in Epi Middle Devonian time. (See pages 68, 94.)

Previous to the shattering, fractures of a different kind were formed in the granodiorite. These are very persistent and some can be traced for as much as two miles along the strike, which lies at 150°. These fractures were subsequently occupied by lamprophyre dykes and mineral lodes. Smaller complementary fractures were formed simultaneously along an E-W strike. These will be discussed in greater detail at a later stage.

The granodiorite has intruded the Ordovician sediments but is older than the Snowy River Volcanics. In most places the granodiorite-Ordovician contacts do not present any unusual features. There is, however, one outstanding exception. A long narrow tongue of Ordovician rocks from 200 to 800 yards wide extends from near the junction of the Suggan Buggan River with the Snowy in a direction 150° for about 2½ miles. (See Fig. 2.) Continuing along the same strike, a large fracture extends from this tongue for another two miles until it disappears beneath the rhyodacite. The fracture is a broad mylonitised zone of granodiorite up to 100 ft. wide (Hand specimens K2, K3, K4, K5). It contains numerous brecciated inclusions of Ordovician sandstones. The north-east granodiorite-Ordovician contact was discussed previously; it has been crushed and brecciated, but it is nevertheless a normal intrusive contact. The south-west contact is a fault for some distance at least, since the fracture zone mentioned above is continuous with it.

At first sight, these relationships suggest that the elongated inlier of Ordovician rocks owes its existence to the fault just mentioned. However, it will be shown at a later stage that the granodiorite block south-west of the fault has moved *downwards* along the fault. This proves that the south-west boundary of the inlier was not created by faulting, and that this elongated inlier was, in fact, in existence before the faulting occurred. The fault has occurred along a normal granodiorite-Ordovician contact already in existence. This interpretation is proved by an examination of the metamorphic aureoles of the granodiorite. The metamorphism is strongest at *both* boundaries and becomes less pronounced towards the centre of the inlier. Consequently the south-west boundary must originally have been of normal intrusive origin.

The question is now raised regarding the origin and significance of this long narrow tongue of Ordovician rocks together with the presence of Ordovician fragments in the mylonite zone farther along the same strike. The feature is clearly of primary origin and is connected with the mechanism of intrusion of the granodiorite. The intrusion process has evidently been controlled by major fractures.

The presence of numerous fragments of Ordovician sediments in the mylonite zone proves that large blocks of Ordovician sediments must either lie enclosed below in the granodiorite along the fault line, or else they have existed previously and have been removed by erosion.

In Victoria, similar "screens" of sedimentary blocks occur at the junction of two separate intrusions at Powelltown and Everton (E. S. Hills, personal communication), and in the Strathbogie Ranges (D. White, personal communication). It is this fact which suggests that the screen described above may have a similar origin, and may lie along the boundary of two distinct phases of the one intrusion. Petrologically there does not appear to be any difference in the two phases; however, it is noticeable that the granodiorite north-east of the contact contains far more xenoliths.

In most places the granodiorite has formed an aureole of low grade hornfels in the sediments. However, in one area near the roof of the batholith metamorphism of a different kind has occurred. Granitization of large xenoliths of Ordovician sandstone has taken place, giving rise to an end product of granitoid appearance. The xenoliths thus granitized range in size up to one hundred yards across and occur about one mile along the spur leading north from the Sugarloaf.

The transition between slightly granitized bedded sediments and a completely granitoid rock can be followed without difficulty in the hand specimen. In hand specimen B12 the bedding of the original sandstone has been retained, only the bedding now consists of alternate bands rich in biotite, quartz-felspar, and pure felspar, about 1 to 3 millimetres wide. In B11 also the original bedding has been completely retained. In B10, B9 and B13, traces of the original sedimentary structure have been obscured and a granitoid rock consisting of felspar biotite and quartz results.

The changes may be followed under the microscope but subsequent alteration obscures some of the features. Most of the felspars have either been kaolinised, or altered to aggregates of micaceous minerals—muscovite, green biotite and chlorite. The original brown biotite has also been extensively chloritised. The widespread alteration is probably due to contact metamorphism by rhyodacites of the Snowy River Volcanics which would originally have overlain the granitised sediments at no great height. They have now been removed by erosion.

Slide 7624 shows the process of granitization of a medium grained impure sandstone in the earlier stages. Biotite is abundant and possesses a preferred orientation parallel to the bedding (which, however, is not as well displayed in the slide as in the hand specimen). The biotite is invariably partly chloritised and bleached by subsequent alteration. Innumerable kaolinised felspar crystals are present. Mostly they are about the same size as the quartz grains and appear to be developing interstitially to the latter. They appear to have replaced completely the cementing medium which originally bound the grains together, rather than the quartz grains. Biotite on the other hand has replaced both cement and quartz grains in its efforts to form euhedral crystals. On one edge of the slide, a veinlet about 1 millimetre wide of coarse orthoclase crystals has developed parallel to the bedding.

No. 7623 shows the process further advanced in what was originally a fine-grained greywacke. The interstitial felspar has commenced to replace the quartz grains more extensively than in 7624. A vein of orthoclase parallel to the bedding likewise occurs in this specimen. No. 7626 shows a coarse-grained sandstone being replaced by felspars which are either kaolinised or represented by pseudomorphs of micaceous minerals. The felspars, both orthoclase and plagioclase, are in the process of replacing quartz along intergranular boundaries and are tending to attain a euhedral shape at the expense of the quartz grains. In one corner a felspar porphyroblast has developed consisting of an aggregate of distinct crystals of orthoclase and plagioclase. No. 7622 shows the same process. There has been, also, some recrystallisation and grain growth of quartz in the specimen. No. 7624

shows the selective nature of the replacement of a bedded sediment. Pure quartzite layers have undergone little change, but adjacent layers, originally richer perhaps in argillaceous material, have been extensively replaced.

No. *7627* shows an advanced stage of granitization with euhedral-subhedral porphyroblasts of felspar up to 3 millimetres across developed right throughout a sandstone. As usual, the felspars have either been kaolinised or completely replaced by micaceous aggregates.

The introduced felspar is usually orthoclase, although albite is common in places.

One of the earliest stages in the process of granitization appears to be the development of biotite, probably largely from material contained in the original impure sandstone. It is noticeable that in the more quartzitic bands biotite is not common. The early growth of biotite is seen on slide *7624* where biotite is extensively developed in euhedral crystals whereas the felspars only occur at grain interstices in small anhedral crystals. At a later stage, felspathization becomes more marked, proceeding along the grain boundaries, replacing both quartz grains and the cementing medium. The felspars eventually attain euhedral shape (Nos. *7622*, *7626*) and finally porphyroblasts develop (No. *7627*). At all stages of granitization, thin bands of felspar may develop in lit-par-lit fashion, parallel to the bedding. These bands of felspar could be due to either

(1) the chemical nature of an original layer of the sedimentary rock which may promote preferential reaction with the felspathizing medium;

(2) the higher permeability of some original layers in the sediment which gives easier access to the granitizing medium.

It is not possible to distinguish the more important factor.

The fact that felspathization commences in the interstices between grains, and replacement of quartz grains occurs from the boundaries inwards, seems to indicate that the felspathizing medium was a liquid which penetrated the intergranular boundaries by capillary processes.

The granitization is therefore apparently due to the action of hot aqueous solutions emanating from the granodiorite magma. The fact that the only place where appreciable granitization occurred was near the roof of the batholith is of some significance. At lower levels, sediments have been changed into low to medium grade hornfelses by the granodiorite. These two different types of alteration are probably due to variation in the water content of the original magma. In the region where little water is present, in the magma, hornfels is the typical contact rock but when the magma contains abundant water in solution felspathization of sediments may be the dominant tendency. This fact is in harmony with the views of Emmons (1933) who has pointed out that water and other volatiles tend to concentrate near the roof of intrusions.

Xenoliths. Xenoliths in the granodiorite are sometimes abundant, but their distribution is irregular. Most of them are dark and rich in ferromagnesian minerals. Closer inspection reveals that they are fragments of schists and gneisses (Hand specimens B26, B29, B30, B31, B32). Under the microscope they are seen to consist mainly of cordierite-biotite-sillimanite schists. Cordierite, either fresh or altered to pinite and chlorite, is by far the most abundant mineral present, usually making up the bulk of the rock, e.g. slides *7732*, *7733*. When fresh it often displays polysynthetic twinning. In section *7735* the chlorite derived from cordierite contains large numbers of elongate inclusions of magnetite. The texture is not unlike the characteristic exsolution textures observed in some ore minerals. In this case, however, it is probable

that the magnetite is derived from excess iron present in the rock which could not be incorporated in the cordierite crystals during growth. In places, biotite also has partially broken down to give magnetite. Sillimanite is characteristically associated with cordierite, usually included as fine prisms or fibrous aggregates. In slide 7732 it has developed into much larger prismatic crystals.

The presence of such large numbers of xenoliths of schists and gneisses in the granodiorite is interesting, in view of the fact that the surrounding Ordovician rocks are unaltered sediments, apart from some low to medium grade hornfels at the granodiorite margins.

The schists and gneisses resemble those occurring in the Eastern Victorian metamorphic complex centering around Omeo. The nearest locality where rocks of this type occur is near Bindi, about 30 miles distant.

Two explanations may be advanced regarding the origin of the xenoliths. Convection currents in the magma of the Corryong Batholith may have transported the xenoliths for considerable horizontal distances, thus accounting for their distribution. Alternatively, it may be that the normal unmetamorphosed Ordovician sediments at Deddick pass downwards into a zone of schists and gneisses. Such a gradation has been observed elsewhere in Eastern Victoria. The deep lying zone of gneisses and schists would be caused by an earlier phase of igneous activity. This zone may have been invaded later by normal granodioritic magma, as has happened at Omeo. The later granodioritic magma is thereby able to incorporate xenoliths of schists and gneisses which may be carried up higher in the crust to a zone which had not previously been metamorphosed.

Large garnets occur rarely in the granodiorite at Deddick. They range in size up to half an inch across, and are invariably rimmed by cordierite and biotite. The cordierite is usually altered to pinite and chlorite. These garnets are only found in granodiorite where it is rich in xenoliths. Apparently the garnet can crystallize only from a contaminated magma.

The R.I. of the garnet is 1·80, indicating that it is probably a variety of almandine, and the colour is always red. Small euhedral crystals of magnetite are frequently included (Slide 7737) (Plate III, fig. 4). Surrounding the core of garnet is a reaction rim of cordierite, usually pinitised or chloritised, and surrounding the cordierite is a rim of biotite. These are well displayed in Plate III, fig. 4. The cordierite often contains extremely large numbers of small biotite crystals as inclusions (Slide 7737). Unlike the outer rim of biotite which has developed due to reaction between the cordierite and the magma, these appear to have been formed simultaneously with the cordierite, due to reaction of the garnet with the magma.

The simultaneous formation of biotite with cordierite is probably caused by the inability of cordierite which has developed from the iron rich almandine to hold as much iron as the almandine (Folinsbee, 1941). Accordingly, the presence of excess iron has caused the formation of some biotite.

The subsequent reaction of the cordierite with the magma may likewise be due to instability caused by the cordierite possessing a much higher Mg/Fe ratio than was present in the magma. Cordierite which has crystallized directly from the magma shows no such instability.

Age of Granodiorite. The granodiorite intrudes Upper Ordovician sediments and underlies unconformably the Snowy River Volcanics of Lower Devonian age. In view of the great thickness of the Snowy River Volcanics, and the frequent intercalations of sedimentary rocks, it seems that the formation of the volcanics must have occupied at least a substantial part of the Lower Devonian epoch. Furthermore,

when the considerable length of time necessary to expose the batholith by erosion prior to extrusion of the volcanics is also considered, it seems probable that the granitic rocks must be of Silurian age.

Lower Devonian

The Snowy River Volcanics outcrop over a considerable portion of the area studied. They consist predominantly of rhyodacites with lesser amounts of intercalated latites, sediments and pyroclastics. They rest unconformably upon a basement of granodiorite and Ordovician rocks and have been folded along north-south axes into two synclines separated by an anticlinal structure.

These rocks were first studied by Howitt (1876, 1878) who called them the "Snowy River Porphyries"; this name was changed to "Snowy River Series" by Gaskin (1943). The term "series" however applies to the rocks laid down during one epoch, and in view of the possibility that some of the flows of rhyodacite may be of Upper Silurian or Middle Devonian age, the name "volcanics" has been substituted.

Howitt (1876) made a traverse through part of the Little River Gorge and came to the conclusion that the Snowy River Volcanics consisted of about equal thicknesses of massive quartz porphyries, and felsites, forming a basal group, and fragmental rocks, mainly tuffs and agglomerates, which formed an overlying group. He estimated the minimum thickness of the Snowy River Volcanics to be about 2,000 ft. He also suggested that the contact of the rhyodacites with the granodiorite at Little River was a major fault extending up to Suggan Buggan.

Detailed mapping by the author does not support the existence of a fault, but Howitt's other views are partially substantiated. The thickness of the flows is much greater than that suggested by Howitt, reaching 10,000 ft., of which the bottom 8,000 ft. consists mainly of porphyritic rhyodacites.

The rhyodacites have been extruded in a large number of separate flows, of which three are by far the most important. Petrologically the rhyodacites differ in only minor respects and the recognition of the different flows in the field is often extremely difficult. If the rocks are fresh it is possible to distinguish one flow from another simply upon the basis of texture in the hand specimen. Rarely a microscopic section may be necessary. However, extensive secondary alteration is universal throughout these rocks, and if this has gone too far the only way to distinguish definitely is by microscopical examination. Apart from texture, other important criteria which aid in distinguishing flows are colour, nature of weathering, and characteristic xenoliths. The criteria will be dealt with in detail when the petrology of these rocks is described.

At this stage, a discussion of nomenclature may be appropriate. The acidic volcanic flows of the Deddick district have all been called "rhyodacites". This term was applied by Gaskin (1940) and Cochrane and Samson (1947) in their descriptions of similar rocks. The latter authors apparently used this name for two reasons. Firstly two chemical analyses of typical rocks by Teale (1920) showed that they were best described as rhyodacites. Secondly orthoclase phenocrysts were believed to be present as well as plagioclase phenocrysts, although they were much less abundant.

As a result of his work on the Deddick rocks, and a re-examination of Cochrane and Samson's slides, the author now believes that it is very doubtful whether orthoclase phenocrysts are present. It seems quite likely that the "orthoclase" is in reality untwinned albite. If this is so, however, it will not affect the classification proposed, since this finds sufficient justification in the chemical analyses. The high potash content must be contained mainly in the groundmass.

In the Deddick rocks, all stages of albitization of andesine phenocrysts may be observed in some rocks, and it therefore seems reasonable to assume that when an altered looking rock containing only albite phenocrysts is found, these phenocrysts were originally of andesine. Accordingly the name "rhyodacite" has been retained for rocks of this type having regard for their probable original composition, although their present chemical composition might be more akin to that of soda rhyolites.

The Snowy River Volcanics at Deddick may be subdivided as shown in Fig. 3. This has not been drawn to scale.

Deddick Rhyodacites

The Deddick Rhyodacites constitute the basal members of the Snowy River Volcanics. They are widespread in the Deddick-Wulgulmerang area and attain their maximum thickness of about 3,100 ft. in the Little River district. The flows thin out in all directions outwards from Little River. To the east, in the Deddick area, the thicknesses range from about 300-1,000 ft., whilst northwards towards Suggan Buggan the total thickness is only 200 ft. At Campbell's Nob, which is four miles south of the area under consideration, the thickness is about 200 ft.

The Deddick Rhyodacites are probably continuous at the base of the Snowy River Volcanics in nearly all parts of the area. There are only two areas where they do not occur at the contact of the Volcanics and the basement rocks. Both occurrences are due to faulting. At Seldom Seen on the contact along the Buchan River divide, the absence of Deddick Rhyodacite is clearly due to faulting. Fault breccias of Ordovician rocks lie against the Black Mountain Rhyodacite. The fault does not continue as far south as Gelantipy where Deddick rhyodacite is again found to be next to the granodiorite. The other occurrence is at Wheelers Creek where Gelantipy Rhyodacite rests against Ordovician rocks. This is likewise due to faulting.

The Deddick Rhyodacites are made up of a group of several separate flows interbedded with which are occasional thin sedimentary beds, a latite flow, and two flows of "minor" rhyodacites. Petrologically the Deddick Rhyodacites may be divided into two different types. Gradations between these two types occur near the top of the group.

The most striking is a strongly porphyritic rock, light coloured when fresh (Hand specimens D7, D10) which may turn to reds, browns, purple or dark green when weathered. (Hand specimens D6, D9, D12.) D9 is a typical example of porphyritic Deddick Rhyodacite. The hand specimen is a brown porphyritic rock containing phenocrysts of quartz and felspar up to 5 mm. across, and occasional smaller chloritised biotite phenocrysts, set in a fine-grained groundmass. Felspar phenocrysts are in excess of quartz, but quartz phenocrysts are frequently larger than the felspars.

Under the microscope (slide 7644) the felspars are seen to consist of albite $Ab_{93}An_7$. The felspar is euhedral to subhedral in form. Some albite phenocrysts are seen to consist of clots of several crystals twinned in a very complex manner. Alteration is universal, usually in varying degrees to sericite and kaolinite. A few anhedral quartz phenocrysts are present, reaching 4 mm. in size. These are invariably cracked and often show traces of resorbtion by the groundmass. They usually contain numerous embayments and inclusions of groundmass material, sometimes glassy, sometimes crystalline.

Biotite is present as a few phenocrysts up to 2 mm. across. It is invariably altered and bleached, mainly to chlorite, epidote, sphene and leucoxene. Associated

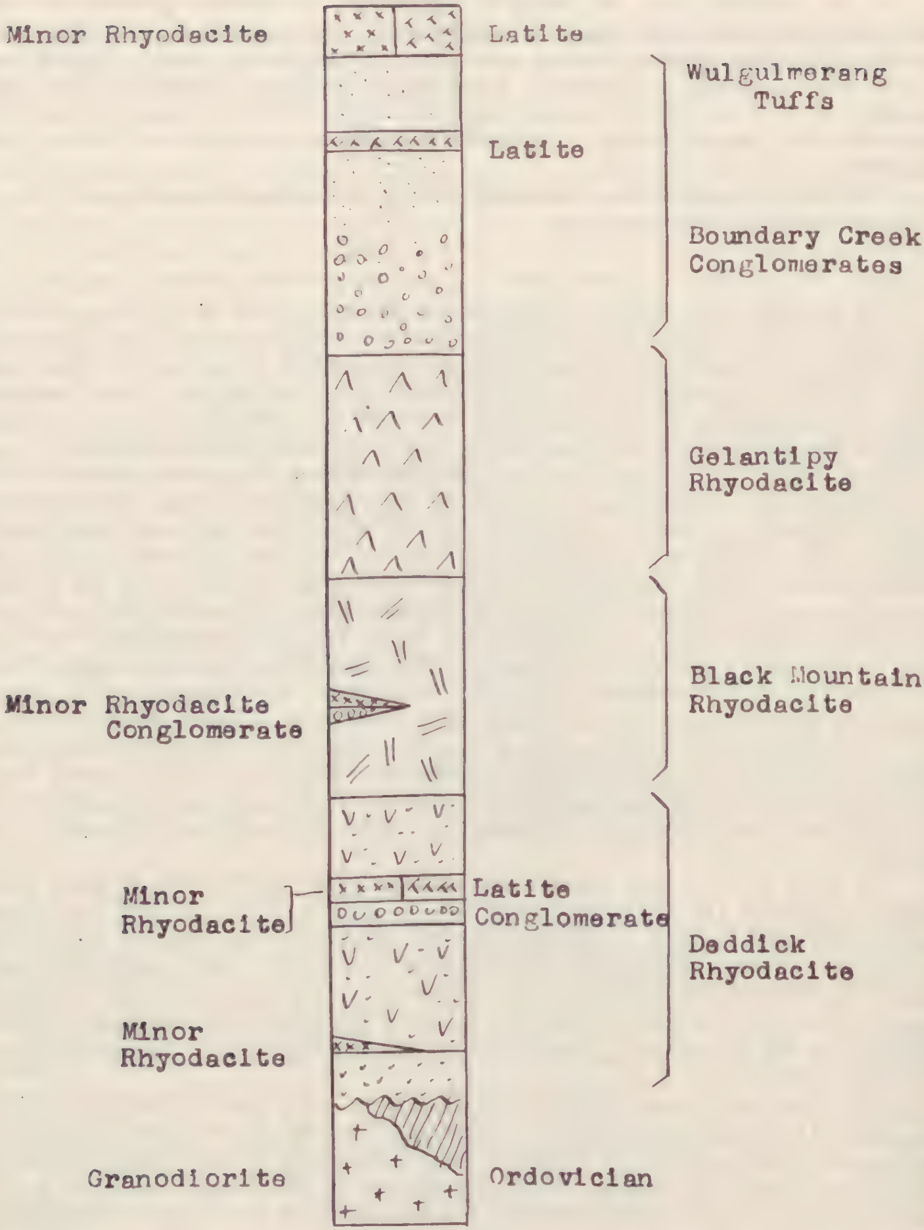

Minor Rhyodacite
Latite
Wulgulmerang Tuffs
Latite
Boundary Creek Conglomerates
Gelantipy Rhyodacite
Black Mountain Rhyodacite
Minor Rhyodacite Conglomerate
Minor Rhyodacite
Latite
Conglomerate
Deddick Rhyodacite
Minor Rhyodacite
Granodiorite
Ordovician

FIG. 3

with the biotite there are a few zircons and an occasional large apatite prism. Alteration to secondary muscovite along cleavage planes is also quite common. The groundmass consists of a microcrystalline aggregate of alkali felspar and quartz. Finely divided chloritic material and hydrated iron oxides derived from magnetite particles are responsible for the greenish brown colour.

No. 7636, coming from about half a mile east of the Sugarloaf, is fairly similar to No. 7644. An interesting feature of the rock is the presence of coronas of alkali felspar around quartz phenocrysts. They appear to represent orientated overgrowths, and extinguish uniformly.

No. 7635 is a slightly sheared rhyodacite taken at the granodiorite contact near the Sugarloaf. Its quartz phenocrysts often show evidence of resorbtion. In slide No. 7638 the groundmass is very finely crystalline and it probably represents a devitrified glass. No. 7632 from Little River furnishes another example of alkali felspar coronas in optical continuity with quartz crystals. It also contains a small basic inclusion.

The second type of Deddick Rhyodacite is exemplified by hand specimen D16. It is a hard, light-coloured rock containing occasional small phenocrysts of quartz and felspar, generally smaller than 2 mm. in diameter. It weathers to give a typical bright yellow surface, and when strongly weathered it is difficult to distinguish from a tuff.

Under the microscope the felspars (No. 7633A) are seen to consist dominantly of euhedral crystals of albite $Ab_{94}An_{6}$. A few crystals of orthoclase (?) are also present. Biotite has been completely replaced by epidote and chlorite. Small granules of the former are widely distributed throughout the groundmass. Quartz is common, mostly as very small crystals, but one large phenocryst occurs. A vesicle has been lined with crystalline quartz. The groundmass is a very fine-grained devitrified glass. Some samples (e.g. Nos. 7640, 7643) of this rock display a very well-developed flow structure both macroscopically and microscopically. No. 7640 contains abundant small quartz phenocrysts, which are more numerous and larger than the felspars. It has been subjected to shearing and small veinlets of quartz now occupy the fractures.

The fine-grained Deddick Rhyodacite forms the earliest flow. It outcrops along most of the north-south striking contact at Little River. However, this early flow does not extend over to the east side of the Snowy River. Overlying this is a thick flow of porphyritic Deddick Rhyodacite. This flow is widespread on both sides of the river and forms the basal flow over most of the Deddick district. Overlying this is a very extensive flow of the fine-grained rhyodacite. The two flows of fine-grained and porphyritic rhyodacite are all that occur on the east side of the river. However, on the west side, around Little River, a considerable thickness of interbedded fine-grained and porphyritic Deddick Rhyodacite together with transitional varieties, overlies the extensive flow of fine-grained rhyodacite. As mentioned before the total thickness of Deddick Rhyodacite in the Little River area reaches 3,300 ft.

Intercalated with the Deddick Rhyodacite are relatively thin beds of sediments and flows of "minor" rhyodacite and latite, which will be described in detail subsequently.

The Deddick Rhyodacites are extremely hard rocks which consequently find topographic expression as high rugged ridges, whereas the rocks on either side—granodiorite and Black Mountain Rhyodacite—have been eroded down to a much lower level (Plate II).

Black Mountain Rhyodacite

Overlying the Deddick Rhyodacite is a second great flow which is remarkably homogeneous in texture and composition. This has been termed the Black Mountain Rhyodacite after an area in which it is well developed. It is both the most widespread and consistently thickest member of the Snowy River Volcanics. Its thickness in the Little River section is 2,500 ft. On the east side of the Snowy River it stretches from Deddick across to Accommodation Creek, in the far east, and southwards to Campbell's Nob. North of Black Mountain as far as Limestone Creek and the Cobberas, the plateau consists of Black Mountain Rhyodacite alone. It then extends continuously southwards to Buchan and Nowa Nowa in two broad parallel belts, forming limbs of a synclinal structure. The Black Mountain Rhyodacite appears to have been erupted in a relatively small number of individual flows. In this district only one discontinuity has been found—a thin band of conglomerate near the base of the flow in the Deddick district.

The hand specimen shows a strongly porphyritic dark rock closely packed with phenocrysts up to 5 mm. across, of quartz and felspar set in a dark glassy groundmass. Around Deddick, the groundmass is usually black although weathering gives rise to a red colour. In the west, however, along the Buchan River divide, the dominant colour is red. There are all gradations between the red and black rhyodacites. Under the microscope the colour is seen to be due to the state of oxidation of the iron ore in the groundmass. In the black rocks (e.g. E2, 7646) the groundmass contains a large amount of very fine dispersed magnetite dust, whereas in the red variety (e.g. E1, 7645) the groundmass contains fine hematite dust. It is clear therefore that the different colours are of little petrogenetic significance.

No. 7645 is a typical example of the black variety. Basically it differs little from the porphyritic Deddick Rhyodacite, and comment will be confined mainly to the differences. The phenocrysts are very numerous and closely spaced, and are set in a very fine cryptocrystalline groundmass which is apparently a devitrified glass. Both albite and andesine are present as phenocrysts, with all the stages of replacement of andesine by albite exhibited. The andesine present is of a composition $Ab_{54}An_{46}$ and has been extensively altered to epidote sericite and sometimes calcite, besides albite. The original ferromagnesian minerals have been completely altered to aggregates of chlorite, magnetite, calcite, sphene, leucoxene and epidote. Most of the pseudomorphs appear to be after biotite but some probably follow hornblende. The pseudomorphs are numerous and range in size up to 3 mm. across. Octohedra of magnetite up to $\frac{1}{2}$ mm. across are common as accessory minerals. Zircon and apatite occur sparingly in euhedral crystals.

Numerous other slides show much the same features. In some, flow structures are well developed in the groundmass. In sections 7646, 7648, 7650, the replacement of andesine by anastomosing veinlets of albite is well displayed. The andesine tends to be slightly more sodic, ranging between $Ab_{60}An_{40}$ and $Ab_{55}An_{45}$.

A second variety of Black Mountain Rhyodacite occurs along the Buchan River divide and in places on the plateau behind Black Mountain, e.g. Mount Wombargo. This variety differs from the normal type in that it is somewhat coarser in texture and possesses a microcrystalline groundmass. The colour of the variety is usually red. Apart from these slight differences, it is similar to the common Black Mountain Rhyodacite (e.g. E13, E14, E15; 7657, 7658, 7659).

In many areas the Black Mountain Rhyodacite contains abundant small xenoliths of sedimentary origin derived from Ordovician rocks (No. 7645) and also of Deddick Rhyodacite (No. 7649).

In the Wulgulmerang Plateau around Black Mountain this flow outcrops over a large area, and has developed quite a good soil. In the Little River Gorge, the Black Mountain Rhyodacite is less resistant to weathering than neighbouring Deddick and Gelantipy Rhyodacites, and a stream valley lies along its outcrop. (Plate II.) However, at the edges of the Wulgulmerang plateau the Black Mountain Rhyodacite forms resistant strike ridges. The long range stretching from Mt. Wombargo southward along the Buchan divide past Mt. Statham and Mt. Murrindal is composed of this flow. Howitt (1876) suggested that this ridge represented the outcrops of a line of median volcanoes which gave rise to the Snowy River Volcanics. This view was based partly upon the fact that these rocks are sometimes a little coarser than the more widespread Black Mountain rhyodacite—a fact which has already been commented upon. However, this fact is of no genetic significance and can only be regarded as a minor textural variation. The field and microscopic evidence shows clearly that the "line of median volcanoes" is in reality the outcrop of the bedded Black Mountain rhyodacite on the western limb of the syncline. (Figs. 1 and 4.)

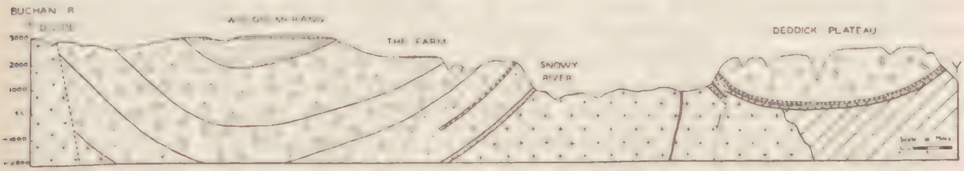


Fig. 4

Gelantipy Rhyodacite

The Gelantipy Rhyodacite occurs only on the west side of the Snowy River, where it overlies the Black Mountain Rhyodacites. In the Little River Gorge it is about 2,700 ft. thick. It maintains and possibly increases this thickness towards the south. However, it is not found in the northern part of the area, being suddenly cut off by a major fault, trending east-west, just south of Black Mountain. It is found along the fault, but is only a few hundred feet thick. The significance of this feature will be considered later.

The Gelantipy Rhyodacite outcrops in two parallel bands striking north-south; one near the Buchan Divide and one in the Little River-Farm area. These two outcrops dip inwards, and form a synclinal structure. Towards the south the outcrops converge at Gelantipy, thus forming a basin-shaped structure open at the northern end. It then extends continuously southwards for a considerable distance. Reconnaissance mapping indicates that it dies out just north of Murrindal.

Thin sections of the Gelantipy Rhyodacite reveal close affinities to the Black Mountain Rhyodacite. A notable feature, however, is the almost complete absence of ferromagnesian phenocrysts of pseudomorphs in the later flow. (Slides 7660, 7661.) An occasional small crystal of magnetite is all that occurs. The quartz phenocrysts are about as numerous as the felspars and in contrast to the Black Mountain Rhyodacite display a strong tendency to form idiomorphic doubly terminated hexagonal pyramids and prisms. Furthermore, these crystals are not embayed or cracked nearly as much as those in that flow. The felspars consist of albite $Ab_{98}An_2$ and a small amount of residual andesine. Xenoliths are very common and have often been partially melted and drawn out in the direction of flow. Xenoliths include sedimentary rocks (from the Ordovician basement) tuffs, Deddick Rhyodacites, and intermediate rocks.

When fresh the Gelantipy Rhyodacite from different localities is fairly homogeneous in texture and composition. However, because of secondary alteration, the hand specimens display a bewildering variety of appearances, and recognition of this rock in the field is often a difficult matter. Relatively fresh specimens are difficult to procure—the freshest seen by the author occur in the bed of the Little River Gorge and in some deep roadside cuttings directly overlooking the Little River Gorge. Even in these (slide 7660) the felspars are somewhat sericitised. When fresh the rock is seen to be of ordinary porphyritic texture with quartz and felspar phenocrysts set in a grey glassy groundmass. The main difference from the Black Mountain Rhyodacite is the smaller size of phenocrysts and the more open packing. No attempt will be made to describe the numerous varieties of weathered Gelantipy Rhyodacite, but a representative selection has been placed in the Melbourne University rock collection. Microscopically the principal effect of weathering is seen to be complete seriticisation of felspars (slides 7662, 7663). It is strange that the Gelantipy Rhyodacite which is so similar to the Black Mountain Rhyodacite exhibits such a different behaviour during weathering. This is possibly due to the inherent properties of the groundmass which in each case is a devitrified glass. Slight differences in chemical composition in glasses are frequently known to cause considerable difference in their physical and chemical properties. It may be that the fact that the glass of the Gelantipy Rhyodacite is apparently poorer in iron and magnesium than that of the Black Mountain Rhyodacite is responsible for the different behaviour.

Economically the Gelantipy Rhyodacite is of no importance. Nowhere has it developed a decent soil; the outcrops have given rise either to rocky ground supporting inferior timber, or in more deeply dissected areas, to gorges with precipitous sides, as at Boundary Creek and Little River.

The Gelantipy Rhyodacite has been erupted in several flows which are often separated by thin beds of fragmental rocks—mainly tuffs and conglomerates.

These three rhyodacites constitute the major flows in the Snowy River Volcanics, and since they are chemically and texturally so similar, it has been thought advisable to set out the criteria for differentiation in tabular fashion. (Table 1.)

Intercalated Minor Rhyodacites

Associated with the three major flows of rhyodacite are several much smaller flows. They are rarely more than a couple of hundred feet thick, and are of purely local significance. Petrologically they possess certain features in common—they are all of porphyritic texture, but the phenocrysts are generally less than 1 mm. across although they may be closely spaced. A second similarity is that on the whole they are richer in ferromagnesian minerals than the three earlier flows. Indeed, a few of these rocks would almost fall into the quartz latite class. They appear to represent transitional varieties between the major flows of rhyodacite which are low in ferromagnesians, and the latites. A convenient name, to cover all of these small flows, which occur at different horizons is "Intercalated Minor Rhyodacites".

Rocks of this type occur at four separate horizons in the area mapped. On the divide between Old Joe's Creek and Running Creek, a flow about 30 ft. thick occurs below the porphyritic Deddick Rhyodacite. It appears to be occupying a depression in the Ordovician bedrock, and dies out rapidly towards the west. The flow is sheared and has suffered much secondary alteration. It is a fairly quartz rich rhyodacite with a large amount of magnetite distributed throughout. (Section 7664.) A second flow occurs in the Deddick area directly below the fine-grained Deddick rhyodacite and overlying a bed of conglomerate and sandstone. The flow is in places a couple of hundred feet thick and outcrops continuously for a mile and a half in

TABLE 1

Criteria for differentiation of Deddick, Black Mountain and Gelantipy Rhyodacites

MACROSCOPIC

	Colour	Size of Phenocryst	Fracture	Weathering	Xenoliths
Deddick Rhyodacite	Usually white, yellow, etc. Also red, brown, grey.	Large, up to 5 mm. across.	Moderately smooth fracture surface.	Texture easily distinguishable.	Rare.
Black Mountain Rhyodacite	Varies from black - red.	Large, up to 5 m.m. across	Moderately smooth fracture surface.	Texture easily distinguishable.	Common in some areas.
Gelantipy Rhyodacite	Grey, yellow, purple, brown, etc.	Smaller than 3 m.m.	Irregular and jagged surfaces.	Original texture largely obscured. Often resemble tuffs.	Common in some areas.

MICROSCOPIC

	Ferromagnesians	Plagioclase	Quartz	Groundmass	Phenocryst Density
Deddick Rhyodacite	Biotite predominant. Usually recognizable.	Albite	Large crystals Anhedral-Subhedral. Fractured and embayed.	Microcrystalline.	Variable
Black Mountain Rhyodacite	Completely altered to chlorite and epidote pseudomorphs.	Andesine being replaced by albite.	Large crystals Anhedral-Subhedral. Fractured and embayed.	Cryptocrystalline sometimes microcrystalline.	Phenocrysts very closely packed.
Gelantipy Rhyodacite	Very rare.	Albite with a little residual andesine.	Smaller crystals. Less fractured and embayed. Idiomorphic.	Cryptocrystalline. Strong flow structure.	More open packing.

the range lying north of the Sugarloaf. A third flow occurs near the base of the Black Mountain Rhyodacite along the divide between Old Joe's Creek and Running Creek. It overlies a conglomerate. Both lense out rapidly along the strike. It appears that this is a fossil deep lead, the conglomerate representing gravels in an old river bed down which the Minor Rhyodacite flowed. This was subsequently covered by Black Mountain Rhyodacite. This is also the only known location in the area where foreign rocks are interbedded with Black Mountain Rhyodacite. The fourth flow of Minor Rhyodacite occurs in Wulgulmerang, where the Deddick road crosses Little River. It is about 200 ft. thick, and outcrops over 100 acres, lying right near the top of the sequence.

Microscopically the Minor Rhyodacites are ordinary porphyritic rocks containing phenocrysts of quartz, albite, andesine and sometimes biotite, set in a groundmass which is usually cryptocrystalline, but sometimes microcrystalline. The albite is $Ab_{94}An_{6}$ whereas the andesine remnants have a composition $Ab_{54}An_{46}$. The albite is seen to have replaced andesine. Quartz phenocrysts are usually present in smaller amounts than felspars and in some slides (Nos. 7667, 7668) they are comparatively deficient. The ferromagnesians are usually represented by pseudomorphs of chlorite and epidote after biotite and hornblende. In slide 7667, however, green biotite is present and is only moderately altered. In the latter slide nests of epidote, probably pseudomorphic after amphibole, are found. Most of these rocks possess a cryptocrystalline groundmass similar to that of the Black Mountain Rhyodacite (Nos. 7668, 7671). In the latter slide, flow structures are beautifully developed.

In some specimens (slides 7673, 7674) xenoliths are quite common. There are several small inclusions of a fine-grained basic rock. The ferromagnesians have been altered to hematite and magnetite. Xenoliths of mudstone and sandstone also occur.

A characteristic feature of the Minor Rhyodacite near the Little River bridge is the presence of numerous inclusions of chlorite. (G16, 7677.) These occur right throughout the flow. Similar inclusions are found in parts of the second flow of Minor Rhyodacite near the Sugarloaf. (Nos. 7672, 7675.) These inclusions tend to be tabular in shape and are usually lensed out in the direction of flow. They range in size up to a centimetre long. They are far too large to be pseudomorphs after biotite; in any case, their irregular shape precludes this. Closer examination indicates that these are small xenoliths of rhyodacite, which have been incorporated in the magma, and later chloritised. (Slide 7675.) Their irregular lens-like shape is probably due to partial melting and being drawn out in the direction of flow. In slide 7675 and to a lesser extent in No. 7672 the process of chloritisation of rhyodacite can be clearly recognized. The groundmass of the xenoliths is strongly affected, phenocrysts being relatively resistant. The process may be seen in an early stage in the Black Mountain Rhyodacites, particularly along the Suggan Buggan road. Large rhyodacite xenoliths have almost invariably been impregnated by chlorite and all have a green appearance. (Slide 7649.) In this latter slide it is noticeable that the only one of the many xenoliths present which is suffering chloritisation is one of Deddick Rhyodacite. In 7675, however, there are several places where the development of chlorite aggregates seems to be independent of xenoliths. These, however, are only small and probably represent the remains of original biotite crystals.

The origin of this widespread chloritisation is connected with the general phenomena of secondary alteration which is so ubiquitous in the Snowy River Volcanics. This subject has been discussed by Cochrane and Samson (1947) and apart from observing that the types of secondary alteration which they found so

common in the Nowa Nowa district are likewise common throughout the Deddick area, the author has no new data to contribute. Cochrane and Samson maintained that alteration of the chloritic type has been due to "active solutions which were probably formed by groundwaters dissolving out certain elements from the minerals of the volcanic rocks and re-depositing them elsewhere to form new minerals (chlorite, etc.), the channels being provided by the various major and minor fractures produced during the era of compression shear and warping which gave rise to the porphyroids". The author does not believe that this hypothesis explains the fact that complete chloritisation of all ferromagnesians in the Black Mountain Rhyodacite occurs to the same extent in regions which have suffered intense stress and shearing (Little River Gorge) as in places where very little stress has occurred, and no channelways have been opened up causing intimate penetration by ground waters (centre of Deddick Plateau). Accordingly he is inclined to attribute the alteration to the action of late magmatic solutions. It seems likely that the parent magma of the Snowy River volcanics had a fairly high content of water, and that this has been responsible for the alteration when concentrated at the late stages of crystallization.

Cochrane and Samson attribute the development of secondary albite in the Nowa Nowa rocks to the action of late stage soda rich solutions of magmatic origin. The Deddick rocks have suffered an even more intensive albitization than those at Nowa Nowa. In the Deddick Rhyodacite, complete replacement of andesine has occurred whilst considerable replacement has occurred in all other flows. For reasons similar to those suggested above, when considering chloritization the author would agree with Samson and Cochrane that the albitization must have been due to the action of late stage magmatic soda rich solutions.

Latites and Quartz Latites

Cochrane and Samson described an andesitic suite from Nowa Nowa. In view of the analysis of a typical member of this suite by one of those authors showing $K_2O = 3{\cdot}98\%$; Na_2O $2{\cdot}39\%$; CaO $4{\cdot}74\%$, it would be preferable to call these rocks latites and quartz latites. The high potash content apparently resides in the groundmass. Rocks similar to these occur in the Wulgulmerang district. However, they display a more advanced stage of secondary albitization than the Nowa Nowa rocks, the original andesine having been completely replaced by albite. Nevertheless, it has been thought preferable to continue to call them latites and quartz latites.

In the Wulgulmerang area there are three flows of latite present. The bottom flow occurs on the west side of the Snowy River interbedded with Deddick Rhyodacite. It outcrops in the Little River Gorge and extends northwards to Wheeler's Creek, averaging about 100 ft. thick. It spreads out to cover a comparatively large area and attains considerable thickness. Its contacts with the basement rock are steeply dipping and often sheared. It is hard to say whether it is intrusive at this locality, or whether its outcrop is defined by subsequent faulting.

The other two flows occur near the top of the Snowy River Volcanics. One flow is about 50 ft. thick and occurs interbedded with tuffs. The tuffs have been folded subsequently and the outcrop of the flow now possesses a "double-S" shape (see Fig. 1). The second flow outcrops along Wulgulmerang Creek between the Deddick and Black Mountain roads. It is the most recent member of the Snowy River Volcanics in this area. There are two outcrops close together, covering about a square mile.

The basal flow is a dark porphyritic rock containing phenocrysts of felspar up to 2 mm. across, set in a dark groundmass. (Hand specimens H4, H5, H6, H7.) The

slides (Nos. 7681, 7682, 7683, 7684) show that the phenocrysts consist of euhedral albite Ab_{96} An_4. They are usually strongly sericitised or kaolinised. Ferromagnesian phenocrysts are rare, and are completely altered to chlorite or epidote. The originals appear to have been hornblende and biotite.

Quartz occurs very rarely as small partly resorbed phenocrysts in some of the sections and in the groundmass of Nos. 7681, 7682. There is, however, insufficient quartz present to justify calling most of these rocks quartz latites, although No. 7679 has sufficient quartz to come into that category. The groundmasses of Nos. 7683 and 7684 are dark cryptocrystalline devitrified glasses. However, in slides 7681 and 7682 the groundmasses tend to be microcrystalline and consist of alkali felspar, some quartz, and chloritic material.

Slides 7678, 7679 and 7680 come from the top flow. The rock is much the same. The albite phenocrysts tend to be larger, however; up to 3 mm. across. In slide 7678 the groundmass tends to have a trachytic mixture. In the others, however, it is largely cryptocrystalline.

Sedimentary Rocks

Interbedded with the lava flows are numerous bands of sediments and pyroclastic rocks. They may be grouped as follows:

Sandstone	Tuffs
Shale	Agglomerate
Conglomerate	Rhyodacite conglomerate

Of these, the second group is by far the most important, reaching a thickness of 2,000 ft. in the Little River area. The former group occurs very early in the sequence, and consists predominantly of detritus derived from the exposed Ordovician bedrock. Strangely enough, detritus derived from the underlying granodiorite is very rare indeed.

The first group of sediments have evidently accumulated in small lakes formed during intervals in the vulcanism. These lakes have received detritus from the exposed Ordovician rocks probably because these latter tended to occupy the higher parts of the topography due to differential weathering, as occurs at present. Conglomerates with sandstone, quartzite and greywacke pebbles are the most common members. The pebbles are only slightly rounded and have evidently not travelled far. There is little or no sorting. The sandstones and mudstones are of irregular distribution, occurring in lenses in the conglomerate. They show the effects of metamorphism by overlying rhyodacite flows. Slide 7685 is taken from tuffaceous mudstones just below the Black Mountain Rhyodacite near the Sugarloaf. They have been completely recrystallized to a low-grade spotted hornfels. Sandstones and greywackes have been silicified and slightly baked, giving rise to a very hard competent rock, which has become intensely fractured during folding similar to the Ordovician breccias described previously. Conglomerates have behaved similarly. (Slides 7686, 7687; hand specimens J2, J4.) These sections emphasize the lack of rounding of the pebbles, which indicates a nearby source.

A very persistent bed of these sediments about 50 ft. thick occurs immediately above the porphyritic Deddick Rhyodacite and is probably continuous from Wheeler's Creek to Old Joe's Creek, a total distance around the strike of about 8 miles. Smaller lenses of similar sediments are found intercalated with the Deddick Rhyodacite in the vicinity of Little River. The highest stratigraphic position these sediments reach is about 200 ft. above the base of the Black Mountain Rhyodacite—an occurrence which was described previously.

Howitt has described similar sediments from Butcher's Creek (1878) whilst Cochrane and Samson (1947) have also found Lower Devonian sediments near the base of the Snowy River Volcanics near Mt. Tara.

Sediments of the second group—tuffs, agglomerates and rhyodacite conglomerates—occur dominantly at the top of the series, where they reach a thickness of 2,000 ft. They consist mainly of tuffs and rhyodacite conglomerates. True agglomerates are fairly rare. Howitt, in his descriptions, uses the term "agglomerate" to signify any coarse fragmental rock in which are fragments are of rhyodacite. Most of the agglomerates he described are, in fact, conglomerates, containing pebbles of rhyodacite with varying degrees of rounding, in a tuffaceous, water-deposited matrix. Beds which appear to be true agglomerates—i.e., coarse fragmental material ejected by volcanic action—are found rarely along the northern boundary of the fragmental rocks; also occasionally interbedded with Gelantipy Rhyodacite. They can only be distinguished by the complete absence of any rounding on the fragments, which are usually smaller than half an inch in diameter (e.g. hand specimen J17).

Tuffaceous rocks are rare in the lower part of the sequence but become increasingly common higher up. Around Deddick there is one fairly extensive horizon from 25 to 50 ft. in thickness, occurring just below the fine-grained Deddick Rhyodacite. However, the outcrops are discontinuous. It reaches maximum thickness just opposite the Sugarloaf. Apart from this bed, tuffs are absent until the Gelantipy Rhyodacite is reached. Thin beds of tuff and rhyodacite conglomerate occur interbedded in this flow. Overlying the Gelantipy Rhyodacite are the main outcrops of fragmental beds in the area. They occupy a basin-shaped structure measuring about 6 miles in a north-south direction and 3 miles east to west. The maximum thickness of 2,000 ft. is found in the Little River section.

The beds in the basal part of the basin are usually very coarse conglomerates carrying pebbles and boulders up to several feet in diameter, although smaller ones, a couple of inches across, are the most common. These pebbles are dominantly of Gelantipy Rhyodacite. An occasional pebble of granodiorite, slate, sandstone or some other kind of rhyodacite is found. The pebbles display varying degrees of rounding, but mostly it is only slight to moderate, indicating that they have not travelled far. Sometimes they display a crude stratification, with their long axes approximately parallel. They are bound loosely by a relatively small amount of soft tuffaceous matrix. Sometimes, however, this matrix has become silicified and hardened, and the conglomerate as a whole then becomes a very tough and resistant rock. They have been called the Boundary Creek Conglomerates, because of the fine exposures and great thickness at the head of the Boundary Creek Gorge.

The thick beds of coarse conglomerate tend to become finer grained as one proceeds upwards in the succession where fine-grained tuffs become dominant towards the top. However, thin lenses of conglomerate still recur at different places, even near the top. Small flows of Gelantipy Rhyodacite are also to be found interbedded with the fragmental rocks, mainly towards the base.

The thick beds of tuff overlying the Boundary Creek Conglomerates have been called the Wulgulmerang Tuffs. They are usually light-coloured fine-grained rocks, often showing well-developed bedding indicative of subaqueous origin. Apart from a small amount of intermediate tuff associated with the latite flow, and a little basic tuff near the Sugarloaf (slides 7690, 7691), they are all acidic, carrying fragments of quartz, altered felspars and ferromagnesians in a fine-grained matrix (J9, J10). Some of the tuffs have the appearance of arkoses—they are seen to consist of small

grains of quartz and felspar closely packed together with little cementing material (J14, J15). When tuffs such as these become silicified they are very difficult to distinguish from normal rhyodacites.

Dykes Associated with Snowy River Volcanics

In the Deddick granodiorite there are three dykes which were mapped first by Ferguson (1899). They are up to 3 miles long and have a variable width, averaging about 50 ft. The strike varies from north to north-west. These dykes have been fractured by tectonic forces but not as strongly as the granodiorite. Petrologically they are extremely similar to the bottom flow of latite stretching from Little River to Wheeler's Creek, and require no further description (slide 7699, hand specimen K6). It is probable that the latter represents the effusive product of the dykes.

Deddick Rhyodacite occurs as dykes in a few localities. The fine-grained variety has been intruded in several places along the major fracture in the granodiorite between the Sugarloaf and the Snowy River. The rock frequently has well-developed flow structures which indicate a westward dip (hand specimen K1, slide 7694). These intrusions are as much as 40 ft. thick in places. Smaller dykes of Deddick Rhyodacite ranging up to about 10 ft. wide also intrude the granodiorite along a general north-west strike. Two have been mapped and it is probable that others occur.

Structural Relations of the Snowy River Volcanics

It has been indicated previously that the Snowy River Volcanics rest unconformably upon a bedrock mainly of granodiorite, together with Ordovician sediments. Fig. 4 shows a complete east-west section from Accommodation Creek to the Buchan River. It shows that the volcanics on either side of the Snowy River have been folded into two synclines striking north-south, separated by a partially denuded anticlinal fold, over the Deddick Granodiorite. The dips along the granodiorite-rhyodacite contacts wherever measured have been about 50°, and greater. (Small lenses of bedded tuffs and flow lines provide the most reliable means of estimating dip in the volcanics.) The most important syncline is the one passing through Wulgulmerang. This extends continuously down to Buchan and contains a great thickness of volcanics. At Little River the dip is over 50° at the contact of Deddick Rhyodacite and granodiorite. The dip decreases towards the west and at the base of the Gelantipy Rhyodacite is 30° (given by a small interbedded lens of conglomerate exposed in a road cutting). Using these dips as a basis for calculation, the total thickness of the Snowy River Volcanics at Little River is approximately 10,000 ft.

The fact that these folds rest mainly upon a granodiorite basement raises some interesting structural problems—are these folds due to normal compressive movements with accompanying flowage of the granodiorite basement, or are they due to faulting which has caused high marginal dips? Neither of these explanations in their extreme form fits the facts. The possibility that the granodiorite basement has suffered a large amount of plastic flow is ruled out by the fact that no signs of flowage—e.g. gneissic marginal textures—have been detected.

The faulting mechanism was favoured by Howitt (1876) who advocated the existence of a major fault along the Little River-Suggan Buggan contact. Howitt's main reason for this supposition seemed to be the steeply dipping contact, although he claimed to find evidence of shearing at Suggan Buggan. Ferguson (1899) who later mapped part of the Little River contact found no sign of faulting.

The present work confirms Ferguson's views, although occasionally the contacts may be the sites of faults of small displacement. Places can be found (e.g. about 1 mile north along the contact from Little River) where granodiorite and rhyodacite occur within a few feet of each other, with no sign of strong shearing or brecciation.

Furthermore, it is invariably found that the rhyodacites are unaltered, whereas the granodiorite has suffered contact metamorphism. A group of specimens were described previously (slides 7616-17-18) taken from the Little River and Sugarloaf contacts. These showed that the granodiorites had been strongly altered with some development of muscovite, which can be seen in the hand specimens. In contrast rhyodacite slide 7635 taken from the contact is virtually unaffected, save for slight shearing.

The fact that granodiorite at the contact displays the effects of thermal metamorphism means that there has been little or no relative movement between granodiorite and rhyodacite, and consequently extensive faults cannot exist.

However, along the far west contact on the Buchan River divide, near Seldom Seen Lookout, there is some evidence that faulting has occurred. Extensive true fault breccias (hand specimen A9) of Ordovician rocks occur along the contact. The rhyodacite at the contact is the Black Mountain type; Deddick Rhyodacite does not outcrop. However, farther south at Gelantipy, the contact shows no sign of faulting, and a thin band of Deddick Rhyodacite does occur at the contact. This indicates that the above fault is only of local significance.

The solution to the problem of folding seems to lie rather in a combination of the two mechanisms previously considered. As was mentioned earlier, the granodiorite in the area has been strongly fractured and jointed, and slickensides indicating movement along these fractures are very numerous. The joints are so numerous that it would be impossible in most places to find a 2 ft. cube of granodiorite without a few joints traversing it. In a later section it is shown that this intense fracturing and jointing is of Epi Middle Devonian age. It is therefore very likely that they have been formed under the influence of the tectonic movements during the Tabberabberan Orogeny when the Buchan limestones and underlying volcanics were folded.

Apparently, under the influence of these tectonic stresses, the granodiorite has been shattered into small fragments which have suffered relative displacement. The cumulative effect of all these small displacements has caused considerable net vertical movements, analogous to folding. Thus, under compression, the overlying Snowy River Volcanics have been folded into a normal series of anticlines and synclines whilst the underlying granodiorite basement has also yielded with the same result along innumerable faults of small displacement—i.e., a giant gleitbretter effect (see Fig. 5).

The folding has exerted a differential effect upon the fragmental members of the volcanics and the massive rhyodacites. The latter have yielded by flowage and fracturing to give simple open folds. However, the fragmental rocks near the top of the series have been folded disharmonically within the main syncline.

Disharmonic folding of this type is well exhibited along the road near Wulgulmerang Creek bridge. A north-south section of the tuffs over a distance of a few hundred yards is given in Fig. 6.

This type of folding is reminiscent on a small scale of folding of the Juras type, caused by slipping of an incompetent formation over a rigid crystalline basement, and is closely analogous to it. Disharmonic folding also occurs in the Buchan Limestones which also lie in the core of the syncline (Gaskin, personal communication).

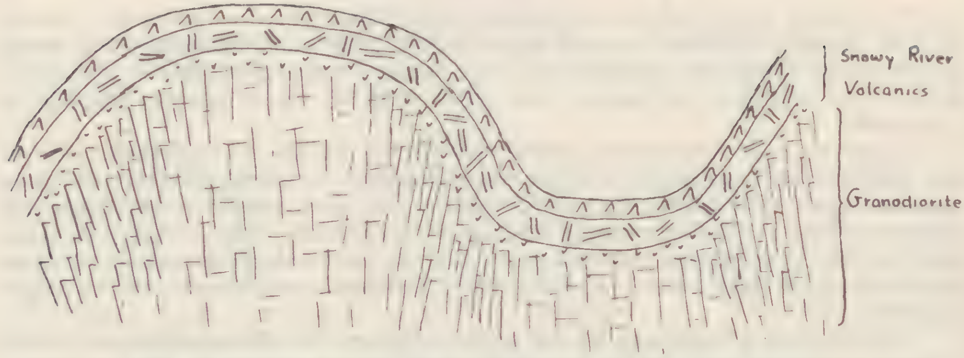


Fig. 5.—"Folding" of Granodiorite and Snowy River Volcanics.

Fig. 6.—Folded Tuffs, Wulgulmerang Creek. Scale 1 in. = 150 ft.

Mechanics of Extrusion

It is also clear that another major structure exists within the area. A consideration of the distribution and thickness of the main flows of rhyodacite indicates that a basin-shaped structure existed in the Wulgulmerang-Gelantipy areas prior to folding.

The Deddick Rhyodacite attains a maximum thickness of 3,100 ft. in the Little River area, but this thickness decreases outwards in all directions to a few hundred feet. Overlying this, the Black Mountain Rhyodacite attains a fairly uniform thickness of 2,500 ft. However, the Gelantipy Rhyodacite occupies a distinct basin, the limbs of the syncline converging at Gelantipy. Farther south, near W-Tree, reconnaissance mapping proves that the Gelantipy Rhyodacite thins out considerably and finally disappears. That the fragmental beds occupy a similar, though smaller, basin, may be seen from the map.

This basin-shaped structure is bounded to the north by a fault, which is a major structural feature of the area, and has for convenience been named the Turnback Fault. It has been traced on the surface for 12 miles, and probably extends much farther. South of Black Mountain it strikes roughly east-west, but as it continues towards Wheeler's Creek it veers around to a strike of about 120°. Still farther to the east it veers more, attaining a strike of 150° near the Sugarloaf, where it disappears beneath the rhyodacites, giving it an arcuate shape. From Wheeler's Creek almost to the Buchan Divide it can be traced continuously. Similarly, from the Sugarloaf to the west margin of the Black Hills where the road enters the Ordovician. However, between this point and Wheeler's Creek, a distance of about 2 miles, the fault could only be picked up in one place—on the spur leading to Mt. Turnback from the 8 mile post on the Deddick road. Here a zone of sheared and silicified rock about 10 ft. wide traverses the granodiorite along a north-west strike (slide 7629 and hand specimen B21). Numerous other evidences of shearing, e.g. large xenoliths of sheared hornfels (slide 7613, hand specimen A11) are found

in the granodiorite nearby. It was not possible to make a detailed search for the fault in the rest of the area because of the steepness of the hillsides and paucity of outcrops.

The dip of the fault is steep to the south, and south-west. This is demonstrated in three localities.

(i) Near the Sugarloaf it crosses a steep spur, and the outcrop shows pronounced vee-ing, indicative of a steep south-westerly dip.

(ii) Near the Black Hills it is intruded by Deddick Rhyodacite which has well-developed flow structures dipping at 70° to the south-west.

(iii) Near Goodwin's Creek, vee-ing of outcrops again indicates a westward dip.

Where it traverses granodiorite, the Turnback Fault may be recognized by a zone of shearing and brecciation up to a hundred feet wide. This is sometimes intruded by Deddick Rhyodacite. These relations are well exhibited between the Sugarloaf and the Black Hills. Hand specimens K2, K3, K4, K5 and slides 7695, 7696 and 7697 display well the intense brecciation. Fragments of Ordovician quartzites, shales and greywackes, the significance of which was discussed earlier, together with fragments of granodiorite, are enclosed in a matrix of mylonitised granitic material. No. 7694 is a slide of an intrusion of fine-grained Deddick Rhyodacite in the fault. It displays well the flow texture. The intrusions of Deddick Rhyodacite are found between the Sugarloaf and the Black Hills. They range up to 50 ft. thick and are discontinuous along the strike, rarely more than a couple of hundred yards long. The fault merges into the south-west border of the Black Hills hornfelses and continues along this contact for a considerable distance, at least as far as the road. No intrusions of Deddick Rhyodacite are found along this granodiorite-hornfels contact, but intense jointing and fracture of the granodiorite parallel to this contact shows its true nature.

In the Snowy River Volcanics, the existence of the fault is clearly disclosed by the geological mapping. Actual physical manifestations are not so easy to recognize because of widespread shearing of the volcanics due to folding. This makes it difficult to be sure that shearing along the fault zone is always due to the Turnback Fault. Intense shearing is, however, displayed by the Gelantipy Rhyodacite above Wheeler's Creek and also other volcanics in Wheeler's Creek. The thin band of Gelantipy Rhyodacite which occurs along the fault is also strongly sheared.

The basin-shaped structure in the Snowy River Volcanics which was described previously is abruptly terminated in the north by the Turnback Fault. A consideration of the mapping indicates that the south-west block has moved downwards, making it a normal fault. The maximum amount of displacement at Wulgulmerang has been of the order of 7,500 ft. A further fact of fundamental importance emerges—the Faulting was synchronous with the extrusion of the volcanics and is therefore intimately related to the mechanism of extrusion. The basin-shaped structure is of primary origin and has been caused by sinking of the down-thrown block of the Turnback Fault at the same time as extrusion. These facts are established by the following data.

(i) Deddick Rhyodacite has been intruded along the fault at Deddick.

(ii) Near the Sugarloaf, the fault disappears under rhyodacites. The thickness of Deddick Rhyodacite north of the fault is only 200 ft. However, south of the fault, on the down-thrown side, the thickness increases suddenly to at least 2,000 ft.

(iii) At Little River, the thickness of Deddick Rhyodacite is 3,100 ft. This is on the down-thrown side of the fault. North of the fault, towards Suggan Buggan, its thickness is at the most 200 ft.

(iv) The Black Mountain Rhyodacite is widespread on both sides of the fault, and appears to maintain a fairly constant thickness of 2,500-3,000 ft.

(v) The Gelantipy Rhyodacite and the overlying fragmental rocks attain a total thickness of 4,700 ft. on the down-thrown block. They extend continuously to the fault where they are cut off completely. No Gelantipy Rhyodacite or fragmentals have been found on the up-thrown block.

These facts prove that there have been two distinct phases of faulting. During the first phase, the Deddick Rhyodacite has apparently risen up the fault plane and flooded the basin on the down-thrown side to a maximum thickness of 3,100 ft. There was enough rhyodacite to fill the basin and spread out in a thin sheet over an extensive area. No movement of the Fault occurred whilst the Black Mountain Rhyodacites was extruded and it was thereby enabled to cover a large area to a uniform depth. The second phase occurred whilst the Gelantipy Rhyodacites and fragmental rocks were formed. These accumulated in the basin on the down-thrown block to a total thickness of 4,700 ft., and therefore the total throw during the two phases around Wulgulmerang must have been about 7,800 ft.

Most of these general relations are depicted in Fig. 7—a north-south section from the Cobberas to Murrindal.

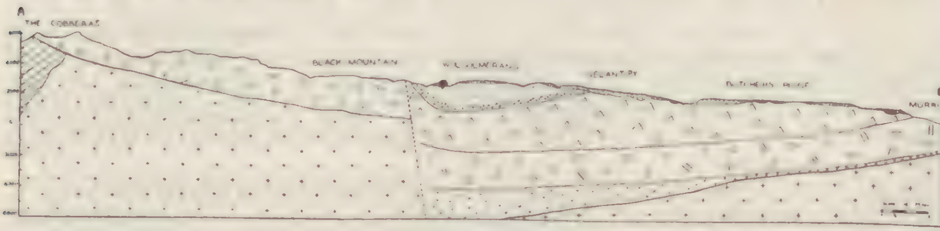


FIG. 7

It cannot be demonstrated conclusively that the major part of the Snowy River Volcanics has been extruded from the Turnback Fault. This is because most of the fault lies through the volcanics, and it is impossible to tell whether the rhyodacites along its course are of intrusive or extrusive origin. However, it seems likely that extrusion of large flows of rhyodacite did occur from this fault in view of the following points.

(i) Its general structural relations which have just been described.

(ii) Around Deddick, where it passes through the granodiorite basement, there are considerable intrusions of fine-grained Deddick Rhyodacite along its course.

(iii) In this general district, the flows of rhyodacite reach their maximum thickness (due to the subsidence caused by the fault synchronously with extrusion). The flows thin out (except Black Mountain Rhyodacite) in all directions outwards from Little River. This suggests that the principal locus of extrusion is in the district. The only feature which could be responsible for extrusion which has been discovered is the Turnback Fault.

(iv) Furthermore, several smaller flows of limited extent occur close to, or along the Turnback Fault. There do not seem to be any obvious feeders which are responsible for them, and accordingly it seems likely that they have been formed by volcanic processes originating from the Turnback Fault. These flows are the upper latite flow and the upper Minor Rhyodacite, at Wulgulmerang, the latite at Wheeler's Creek, the second flow of Minor Rhyodacite at Deddick, and also the tuffs near the Sugarloaf at Deddick.

Although it is believed that the major part of the extrusion came from this fracture, it seems clear that there must have been other smaller loci of extrusion. For example, the three latite dykes, which cover a total length of about 7 miles, appear to have acted as feeders for the latite flow interbedded with the Deddick Rhyodacite. Two other rhyodacite dykes have been mapped and these probably acted also as small feeders. It is highly significant that all these dykes are on the down-thrown side of the Turnback Fault and are closely parallel to that major structural feature. This suggests a genetic connection.

It is probable that there have been several other minor loci of eruption, which have not been discovered. This is suggested by the occurrence of small interbedded flows of rhyodacites and tuffs which lense out in all directions and which appear to be isolated from one another, and for which no feeders have yet been found.

Formation of Turnback Fault

The occurrence of a large arcuate fault along which the inside block moved downward, accompanied by extrusion of great volumes of rhyodacite, immediately suggests cauldron subsidence as the mechanism of extrusion. However, this cannot be so, since the fracture dips in towards the sunken block, which would render impossible the sinking of a large complete block.

In view of this fact, a form of fissure eruption seems indicated. It remains, however, to explain the strongly arcuate nature of the fissure. This is partly due to the influence of existing geological structure prior to faulting—part of the fault is along the junction of two separate phases of the granodiorite intrusions, which are partly separated by an Ordovician screen. However, this cannot be the whole story—it does not, for instance, explain the arcuate dykes of latite in the sunken block which run parallel to the main fracture.

It is possible that the arcuate fault could be explained as due to the action of an asymmetric magma chamber. In view of the eruption of great quantities of effusive rocks, it seems likely that a magma chamber of large extent existed below, in the crust. If such a magma chamber of irregular shape exerted much hydrostatic pressure near its roof, considerable unbalanced stresses would be generated in the roof, and this may result in fracture. This matter has been considered by Emmons (1937), more especially with regard to the formation of vein systems.

Fig. 8 shows the components of stresses which would be set up in the roof of an asymmetric intrusion. It is clear that these stresses would be unbalanced, and that the roof would fracture in the direction indicated if the hydrostatic pressure of the magma was great enough. Furthermore, if the crest of this asymmetric magma chamber possessed an arcuate shape, the outcrop of the fracture formed would also be arcuate. It is suggested that the Turnback Fault is due to such a mechanism. The fracture would initially be a steeply dipping reversed fault, as may be seen from the diagram showing the principal stresses.

This fracture would open the way for extrusion of rhyodacite, which occurs predominantly from the main fracture, and also to a small extent from lesser frac-

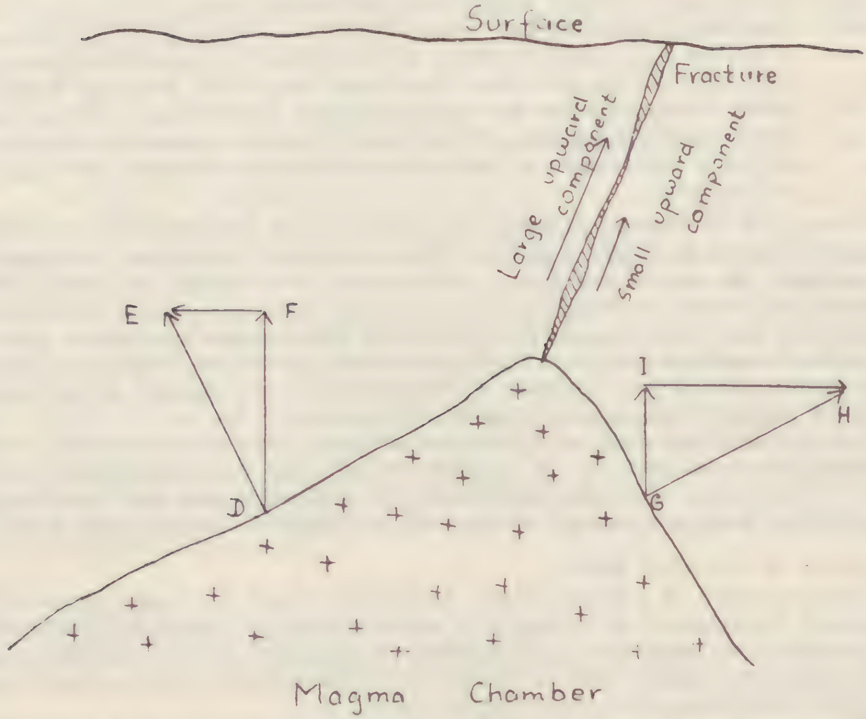


Fig. 8.—Showing resolved components of forces acting on walls of an asymmetric magma chamber under hydrostatic pressure. Unbalance upward components cause fracture. (Modified after Emmons, 1937, p. 24)

tures formed synchronously with the main fracture. Immediately the nature of the fault changes. As extrusion occurs, the pressure on the upthrust block is reduced, and it commences to sink, or rather, sag along the fracture, thus making the fracture into a normal fault. With continued extrusion the block sags further and further forming a basin on the down-thrown side into which the effusive rhyodacites flow, finally accumulating in great thickness. It is clear from the stress diagram that when the level of the magma chamber is falling, the block overlying the less steeply dipping side of the magma chamber will sag the most, and will move downwards relatively to the other block.

Petrogenesis

At Deddick, the Snowy River Volcanics attain a maximum thickness of 9,500 ft. of rhyodacites and acidic fragmentals, and about 500 ft. of latites. No basic flows occur. The large flows of rhyodacite are all of highly acidic character; judging from similar analysed rocks at Nowa Nowa they all contain more than 70 per cent silica. Linking these with the latites are some small flows of Minor Rhyodacite. These flows vary irregularly in composition from normal rhyodacite to quartz latite. Thus the transitional character of these rocks suggests that the rhyodacites and latites are related by some form of magmatic differentiation.

There are six horizons at which Minor Rhyodacites and latites occur in the area, and they all have one thing in common. Wherever these relatively basic flows

occur, they overlie beds of tuffs or sediments. In other words, whenever a more basic flow has been extruded, a considerable time interval has elapsed between the last extrusion of normal rhyodacite and the extrusion of more basic rock. This relation can hardly be fortuitous. It suggests that the mafic rich Minor Rhyodacites and latites have differentiated in some way from the parent rhyodacite magma; differentiation only occurring when an appreciable time lapse has occurred in the extrusion of rhyodacite. A way in which this could occur is described below.

In a preceding section reasons were advanced for believing that a magma chamber had once existed, connected by a conduit (the Turnback Fault) joining the crest to the surface. If, during a break in extrusion (during which tuffs or sediments were laid down) differentiation took place at the roof and margins of the magma chamber resulting in the formation of more basic magma, then at the next period of extrusion, some of this basified magma would come out of the vent first, and form a small flow which would later be covered with normal rhyodacite. Such a process would explain the observed facts, viz.:

(i) The small amount of basified magma compared to normal rhyodacite.
(ii) The frequent and intermittent extrusion of this magma.
(iii) The fact that it has only been extruded after a considerable time break in the extrusion of normal rhyodacite. (Indicating that a certain amount of time is necessary for differentiation to take place.)

Differentiation of this type has occurred in numerous acidic intrusive bodies which possess basified borders and roofs. Syenites, quartz syenites, diorites, quartz diorites, monzonites and quartz monzonites are the rocks most commonly met with in the border and roof zones of acidic batholiths and stocks, although more basic rocks—gabbros and shonkinites—also occur. The relationship between the inner acidic rocks and these marginal, quantitatively unimportant more basic rocks is frequently gradational, and it is reasonably clear that the basified borders have often developed by some process of differentiation from the parent acidic magma.

Accordingly it is suggested that the occurrence of Minor Rhyodacites and latites in the Snowy River Volcanics is due to differentiation of a parent rhyodacite magma—the differentiation taking place near the roof of the magma chamber during intervals in extrusion. The differentiation is exactly analogous to the formation of a monzonitic border and roof phase (latite) to a granodiorite connected by transitional stages (Minor Rhyodacite). Examples of this type of differentiation are Vermilion Batholith (Grout 1925); Newry Granodiorite (Reynolds 1934); Yogo Peak (Weed and Pirrson 1899).

Basic magmas are commonly regarded as being the immediate parents of acidic and intermediate magmas but it would be rather artificial to assume that a basic magma was the immediate parent of the rhyodacites. Firstly, no basic flows occur in the area (although a small flow is found near Buchan). Furthermore, the total thickness of rhyodacite—9,000 ft. as against only 500 ft. of quartz latite—makes it difficult to regard the enormous thickness of acidic rock as derived from the small amount of latite, which was itself derived from a basalt which is not even found. It seems preferable to regard the parent magma as primary in exactly the same sense as the parent magmas of acidic batholiths are being commonly regarded as primary.

Epi Middle Devonian

The lamprophyre dykes and mineral deposits of the Deddick area are probably of this age. The lamprophyres intrude rhyodacites of the Snowy River Volcanics along the Suggan Buggan road, and also about half a mile east of the Sugarloaf.

The mineral lodes are found to cut the dykes. At Buchan, similar dykes associated with galena deposits are found in the Middle Devonian limestones (Howitt 1878). An upper limit to their age is derived from structural data. The lodes and dykes, together with the granitic country rock of the area, have been severely fractured and deformed. The universal fracturing and jointing has been caused by the Tabberabberen Orogeny (Epi Middle Devonian) which was responsible for folding the Snowy River Volcanics and the overlying limestones.

The dykes and mineral lodes of the Deddick area have been described by several workers—Sterling (1899), Dunn (1909), Jenkins (1899), Ferguson (1899) and Whitelaw (1921), but Ferguson's account is by far the most important and comprehensive. He mapped the lodes and dykes, noting their mutual relations and described the more important lodes. Fig. 2 is based largely upon Ferguson's map of 1899, although the author has inserted several dykes not mapped by Ferguson, together with the Turnback Fault and other details.

Lamprophyre Dykes

These dykes fall into two distinct groups—biotite monchiquites and spessartites. Biotite monchiquite occurs in only two small dykes, whereas the spessartites form a dense swarm.

Biotite Monchiquite

Two small dykes about one mile north-north-west of the Sugarloaf are found to be of biotite monchiquite. These were discovered and mapped by Ferguson, who called them biotite olivine diabase. They average about 2 ft. wide and cannot be traced more than 100 yds. separately. It is possible, however, that they are connected since they lie on approximately the same strike, parallel to the spessartite swarm. They have been sheared and fractured, and hence are earlier than the Tabberabberan Orogeny.

Macroscopically they are seen to be porphyritic in texture, with phenocrysts of biotite up to $\frac{1}{2}$-inch across, apatite prisms up to $\frac{3}{4}$-inch long, olivine, and other unrecognizable minerals, sparsely distributed in a fine-grained black groundmass. In one specimen, an inclusion of dunite occurs.

Under the microscope the phenocrysts are seen to consist of biotite, apatite, enstatite, olivine (largely serpentinised), magnetite and rare augite in a groundmass of small augite prisms, magnetite and some olivine set in a glassy base.

Biotite occurs commonly in phenocrysts up to $\frac{5}{8}$-inch across. Mostly it occurs in rounded crystals of irregular shape, but sometimes in euhedral crystals of hexagonal outline. It is an iron rich variety with $\eta\beta \simeq \eta\alpha = 1{\cdot}67$ and is pleochroic from green brown to black. The optic axial angle is very small, less than 10° (slide 7704). The phenocrysts are commonly distributed throughout the dyke and show no preferential orientation. Crystals of apatite are commonly included. Some of the smaller biotite crystals are breaking down into aggregates of magnetite, hematite and indeterminate secondary minerals, evidently due to a process of resorbtion. Some large crystals of magnetite associated with a large biotite phenocryst slide 7728 also appear to be derived from the resorbtion of biotite.

The only phenocryst attaining comparable size with biotite is apatite which occurs sparsely throughout the rock in long slender prisms up to $\frac{3}{4}$-inch long, although the average length would be considerably less than this (slide 7703 and hand specimen L2). Olivine is a very abundant phenocryst although it is usually much altered. Olivine is also an important constituent of the groundmass in which it occurs in small subhedral grains. There is a complete gradation in size between

the groundmass olivines and the phenocrysts. A fairly fresh phenocryst in slide 7729 gives a good interference figure, which indicates a very high optic axial angle, close to 90°. The olivine therefore is close to forsterite in composition. Most phenocrysts have suffered considerable secondary alteration, generally to plate-like masses of serpophite, usually surrounded by rims of antigorite. Occasionally carbonates (magnesite?) are present in the cores. Iddingsite is also often present as an alteration product. Apart from the olivine, there is little secondary alteration in the rock. Enstatite occurs sparingly as small phenocrysts up to 1 mm. across, but not in the groundmass. The phenocrysts are small anhedral crystals, surrounded by reaction rims which are usually indeterminate. However, two crystals in slide 7701 show reaction rims of recognizable augite and phlogopite. In Fig. 9a the first stage in

Fig. 9a. — Enstatite (E) with reaction rims of augite (A), and phlogopite (P).
(s)—Symplekite.
(c)—Chlorite and incipient phlogopite.

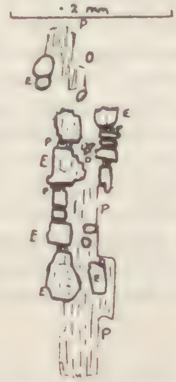


Fig. 9b. — Enstatite (E) with phlogopite (P) reaction rim.

the reaction seems to be the formation of a symplekite of chloritic material and crystallites of augite. At a later stage the augite crystallites grow and coalesce. The augite has the same structural orientation as the parent enstatite, and extinguishes uniformly. A couple of incipient crystals of phlogopite are seen in the process of development from the symplekite. In Fig. 9b, the development of phlogopite directly from enstatite is shown. The first stage seems to be the development of a chloritic material along the cleavage and margins of the enstatite, and this later develops into phlogopite. The phlogopite is light green in colour and slightly pleochroic.

Augite occurs abundantly in the groundmass as small euhedral prisms. It is also found very rarely as small phenocrysts up to ½ mm. across. The groundmass is composed dominantly of small euhedral augite prisms which have an extinction angle of 45°. They lie in an isotropic groundmass which may contain analcite—it has a refractive index less than balsam, and is gelatinised by warm concentrated nitric or hydrochloric acids.

Magnetite is an important constituent of this rock. It occurs both as large "phenocrysts" and scattered thickly throughout the groundmass in small octahedra. An important feature of the magnetite in the groundmass is that it has crystallised before augite. Whenever the two minerals are in contact, it is the augite which includes or tends to include the magnetite. Another unusual feature is the occur-

rence of magnetite "phenocrysts" with coronas of augite. These "phenocrysts" range in size up to 5 mm. across. They are invariably rounded. Some consist of pure magnetite, whilst others consist of extremely fine intergrowths of magnetite, pyroxene and sometimes other indeterminate minerals. Usually they possess a thin corona of augite which extinguishes uniformly. Sometimes crystals of apatite may occur as inclusions.

There is a gradation in size between the magnetite phenocrysts and the magnetite of the groundmass although it is rather abrupt. There is also a complete gradation between phenocrysts consisting predominantly of magnetite, to those consisting of intergrowths of magnetite and augite, continuing down to the stage where magnetite occurs as inclusions in an augite crystal. Clearly, all these features which have been described are diagnostic of a reaction relationship between magnetite and augite. A series of these intergrowths is shown in Fig. 10.

When some of the magnetite phenocrysts are examined using high-power magnification and intense illumination it is found that they consist of very finely grained magnetite sometimes intergrown with other minerals (e.g. slide 7705). In this slide, near the centre, the magnetite is intergrown with a brown mineral, optically continuous over the whole area, with a moderate optic axial angle, and apparently optically positive. Near the margins, however, this mineral gives way to solid magnetite, which has an outer reaction rim of augite in places. The same features are noticed in some other sections. The concentration of magnetite (or hematite, as in section 7730) is greatest near the margins. Textures such as these are characteristic of resorbed ferromagnesian minerals. (Larsen 1937.)

Petrogenesis

The first point requiring explanation is the origin of the magnetite "phenocrysts". They must have developed at an early stage of crystallization of the magma, since it has been shown that they precede augite. It therefore seems most unlikly that they have crystallized directly from the lamprophyre magma, since magnetite aggregates of this size and texture are never found in the chilled selvages of basic dykes or flows. It therefore seems probable that they represent resorbed phenocrysts of ferromagnesian minerals, or foreign inclusions of unknown origin. Since the dyke has been intruded through a granite batholith, the incorporation of xenoliths of magnetite seems to be ruled out.

Accordingly it appears that the magnetite phenocrysts must be due to resorbtion of ferromagnesian minerals. There are several lines of evidence which suggest that this is the case.

The only mineral in the lamprophyre capable of furnishing the magnetite phenocrysts from the point of view of both size and composition, is biotite. The magnetite phenocrysts are up to 5 mm. across, and are the largest crystals after biotite and apatite. Furthermore, the biotite is an iron rich variety. All other phenocrysts present in the magma are poor in iron (enstatite, forsterite and apatite). That the magnetite is due to resorbtion of biotite is suggested by

(i) both biotite and magnetite intergrowths are approximately of the same range of sizes, and shape. The biotite occurs in rounded crystals of irregular shape as does the magnetite.

(ii) The biotite commonly contains inclusions of apatite. The magnetite also contains inclusions of apatite of similar size.

(iii) Some of the magnetite phenocrysts have a striated appearance, the striae being due to varying content of magnetite and intergrown minerals. This structure is probably derived from the cleavage of the biotite.

(iv) The occurrence of intergrowths with rims entirely of magnetite, whilst the core is composed of magnetite intergrown with some indeterminate minerals is similar to undoubted occurrences of resorbed biotite described by Larsen (1937). Larsen has also described biotite completely replaced by magnetite.

(v) Some small crystals of biotite can actually be observed to be breaking up into aggregates of magnetite, hematite, and other secondary minerals.

In one crystal (section 7703) the magnetite is confined to the margins of an altered biotite crystal.

The question of resorbtion of complex minerals has been fully considered by Bowen (1928). He shows that resorbtion will take place strictly in accordance with the reaction series. A mineral late in this series, if it should sink into a warmer environment in which earlier members of the reaction series are being precipitated, will react and be converted into the phase with which the magma is in equilibrium. This principle fits exactly the case under discussion.

When magma is intruded into a vertical fissure the earlier portions which encounter the cool country rock first will suffer more cooling than the later portions, which enter pre-heated walls. Therefore, the magma at a higher level in a small dyke will be cooler, and therefore at a later stage of crystallization than the magma at lower levels.

In the upper portions of the dyke, the lamprophyre magma had apparently reached a relatively late stage of crystallization, during which large phenocrysts of biotite were forming. These crystals because of their large size and high density would sink very rapidly, and reach lower portions of the dyke which were at a higher temperature and therefore at an earlier stage of crystallization. In this higher temperature region the minerals crystallizing out were magnetite, olivine, enstatite and apatite. Following the principles developed by Bowen, the biotite which is iron rich has reacted with the residual magma to precipitate not olivine or enstatite which are poor in iron but magnetite.

At a later stage of crystallization, magnetite has ceased to crystallize, and a reaction relation has developed between magnetite and augite. The phenocrysts of magnetite are partially resorbed and rounded, and develop reaction rims of augite. In other cases, the reaction has occurred in the magnetite phenocryst between the grain boundaries, resulting in an intergrowth of magnetite and augite. There are all stages of transition between magnetite phenocrysts with small reaction rims, through magnetite-augite intergrowths, to almost pure augite (Fig. 10).

Thus, crystallization has been dominated by a reaction series similar to that proposed by Bowen. However, there is no evidence of a reaction of olivine to give enstatite. These two minerals appear to have separated simultaneously.

Crystallization of Biotite Monchiquite Dyke

Apatite
Olivine
Enstatite ↗ Phlogopite
Enstatite ↘ Augite
Magnetite ↗ Augite
Augite ——→ (?) Biotite
Biotite ↓ (sinking into warmer environment)
Magnetite ——→ augite

In the mechanism proposed above, it should be pointed out that the distance which the biotite would need to sink would be only of the order of a few feet.

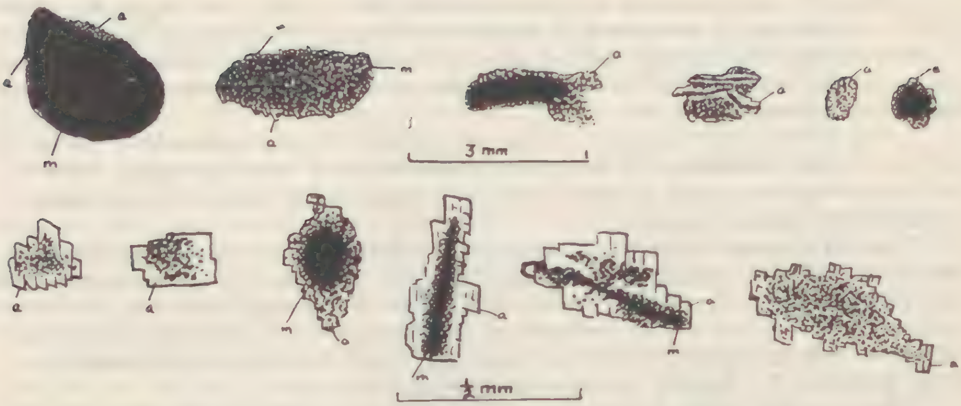


FIG. 10.—Intergrowths and reaction rims of magnetite (m) (black) and augite (a).

The small thickness of the dyke (2 ft.) ensures that rapid cooling with high temperature gradients has taken place. Therefore the biotite would not sink far before encountering a warmer environment.

The mechanism has two implications which require discussion.

The first is that magnetite may in some conditions form an essential part of the discontinuous reaction series of ferromagnesian minerals. As far as the biotite monchiquite cited above is concerned, this contention may be regarded as proved. It seems possible, however, that the magnetite-augite reaction may be more widespread than is sometimes realized. The widespread occurrence of the reverse reaction—the resorbtion of ferromagnesian minerals to precipitate magnetite—is well established. There does not seem to be any *a priori* reason why the resorbtion process should not proceed in the opposite direction with equal facility.

The phase relationships of the ternary system Na_2SiO_3-Fe_2O_3-SiO_2 have been investigated by Bowen, Schairer and Williams (1930). They have demonstrated the existence of a reaction relation between hematite and acmite. In their discussion of that system they suggest by analogy that magnetite may possess a reaction relation to other ferromagnesian minerals. In support of this contention they point out that many ferromagnesian minerals when melted furnish magnetite, "a fact which suggests that magnetite has the same relation to these minerals that hematite has to acmite". This prediction has been completely verified in the biotite monchiquite described above.

Since the magnetite phenocrysts in this rock are reacting to produce augite it follows that the magnetite of the groundmass which crystallized early must also be reacting. A cursory examination does not disclose any obvious reaction relationship between the groundmass magnetite and augite—no signs of resorbtion or coronas. However, more careful observation discloses that a large percentage of the magnetite is closely associated and often included in augite. Where magnetite is densest, very often the augite is also concentrated. Taken by itself, this observation would not be sufficient to establish the existence of a magnetite-augite reaction. However, because of the reasons enumerated previously a reaction must be occurring. It is advisable to remember Bowen's dictum—the fact that one mineral does not display the corona relation to another is no indication that a reaction relationship between the two is not present.

Considerations such as these suggest that early magnetite may often possess a reaction relation to other ferromagnesians without it having been noticed. This applies particularly to basic magmas somewhat richer than usual in alkalis. In magmas such as these, magnetite is often a mineral of early crystallisation, whereas in normal subalkaline basic magma it usually crystallises late.

Bowen, Schairer and Williams' discussion (1930) of the possible courses of crystallisation of the system Na_2SiO_3-Fe_2O_3-SiO_2 make it clear that a magnetite-augite reaction could be of considerable importance in governing the crystallisation and subsequent differentiation of basic alkali rich magmas.

A second implication of the mechanism previously put forward to explain the existence of magnetite phenocrysts is that the biotite phenocrysts crystallised completely within the dyke, and are not of intratelluric origin. In this particular case, it was not possible to obtain a sample of the chilled border zone, and so no definite decision can be given for this particular dyke. However, it might be noted that the biotite phenocrysts show no preferential orientation parallel to the walls of the dyke. If these phenocrysts had been present when the lamprophyre was emplaced it is to be expected that they would show some preferential orientation due to flowage of the magma through the narrow dyke channel.

Some workers (e.g. Bowen 1929) are inclined to infer from the typical panidiomorphic and porphyritic textures of lamprophyres that the initial magma has never existed completely in the liquid state. However, occurrence of a chilled glassy border phase in the lamprophyre described by Campbell and Schenk (1950) show that this is not so. In a camptonite dyke 3 ft. wide, phenocrysts are absent in the chilled border phase, but hornblende phenocrysts increase in size regularly towards the centre where they reach four inches in diameter. The chilled border phase contains only a few crystals of magnetite and olivine.

Actually there is nothing to suggest that these strongly porphyritic textures cannot be explained in terms of current concepts of crystal growth from liquid mediums.

Winkler (1949) has studied the relation between rate of crystallisation and size of crystals for nepheline crystallising from a melt. Measurements of crystal size in a basic dyke (Fig. 11) showed that other minerals follow the same shaped curve. Winkler believes it holds for all crystals.

It will be observed that when a magma cools slowly (e.g. under plutonic conditions) the crystal size is usually not very coarse (pegmatites excepted). However, there is a narrow range of rapid cooling during which crystals very much larger than average size separate. With extremely rapid cooling, the crystal size decreases very rapidly, and a glass may result. The position and magnitude of the high growth rate region depends upon the individual mineral and its environment (especially viscosity). It appears that in lamprophyric magmas which are usually rich in volatiles, and therefore of low viscosity, this high growth rate for ferromagnesians occurs under conditions where the rate of cooling is very high, as would occur in dykes of moderate thickness.

In the dyke described by Campbell and Schenk the conditions are represented by the right hand side of the curve in Fig. 11. The glassy selvage represents the extremely high rate of cooling, whereas the hornblende phenocrysts in the core have been formed under critical conditions near the crest of the curve. On the other hand, in a dyke described by Winkler (1949) the full curve is represented.

It would therefore appear that the texture of the biotite monchiquite described can be explained satisfactorily in terms of rapid crystallization of a magma of low viscosity without introducing assumptions about intratelluric origin of phenocrysts.

Another argument which has been used to support the contention that lamprophyres do not in general crystallize from liquids of their own composition is the fact that the ferromagnesian phenocrysts frequently display signs of resorbtion, and hence cannot be in equilibrium with the surrounding liquid. However, as was pointed out earlier, this is to be expected, since the phenocrysts will tend to sink in the dyke,

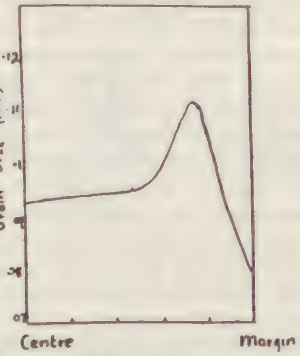


FIG. 11.—Grain size variation of augite in Cleveland Dyke. (*After Winkler 1949, p. 568.*)

reaching warmer zones which are not yet in equilibrium with the phenocryst. Consequently some resorbtion occurs. This has occurred in the biotite monchiquite described causing formation of magnetite phenocrysts. A biotite phenocryst which has become much rounded and partly resorbed is shown in slide 7702.

Spessartites

A swarm of spessartite dykes occur within the area. They are found in a zone between Wheeler's Creek and the Sugarloaf. The great majority possess a north-north-west strike and a vertical dip. All except one of the dykes occur to the west of the Turnback Fault, and increase in density as the fault is approached from the west. The dykes range from 6 inches to 20 feet in thickness and are up to 2 miles in length.

Hand specimens reveal the spessartites to be fine-grained greenish rocks occasionally showing a small phenocryst of felspar or altered ferromagnesian minerals. Small isolated crystals of arsenopyrite, pyrite and chalcopyrite are widely distributed. Sometimes barite and galena are found along mineralized shear planes.

PETROLOGY. M1 is a fairly typical spessartite. The hand specimen shows it to be a fairly fine-grained speckled green rock with occasional phenocrysts of felspar. Small patches of calcite occur, as does also an occasional patch of chalcopyrite. The slide (*7707*) reveals phenocrysts of felspar and altered ferromagnesian minerals lying in a groundmass of felspar laths, chlorite, magnetite, augite, epidote and calcite.

The felspar phenocrysts range in size from 1 mm. downwards, and are transitional in size with the felspars of the groundmass. They are euhedral-subhedral in habit and are usually partly kaolinised. The felspars, both phenocrysts and groundmass, consist of albite and orthoclase in sub-equal proportions. The albite is a sodic variety and has a composition of about $Ab_{96}An_4$.

Ferromagnesian phenocrysts are widely distributed but apart from some exceptionally fresh augites, they are completely altered—mainly to chlorite and epidote. Judging by the shape of the pseudomorphs the original large phenocrysts were

mainly of hornblende, although the fresh ferromagnesians are of augite. The phenocrysts are up to 3 mm. across and are nearly always altered to antigorite. One large phenocryst has been completely epidotised.

The larger phenocrysts have suffered considerable resorbtion and have reacted with the magma to precipitate alkali felspar, which may form coronas. The resorbtion of ferromagnesian phenocrysts in lamprophyres has been discussed previously, and the cases in point may be explained by mechanisms similar to those suggested. In this case, however, the initial alkalic content of the hornblende has been precipitated as alkali felspar when resorbtion occurred, instead of passing into the residual liquid (Fig. 12).

FIG. 12.—Showing corona of alkali felspar (stippled) surrounding epidotised augite (?). Black: iron ore; shaded: zircon.

In other cases, resorbed phenocrysts are surrounded by a corona of extremely minute felspar prisms embedded in chloritic material. In one case, quartz occurs within the core. This appears to be another example of resorbtion.

Slide 7710 is from another spessartite which has suffered more extensive secondary alteration. Large amounts of calcite are disseminated throughout the rock. Small interstitial anhedral crystals of quartz, often showing undulose extinction, are widely distributed. They appear to have been introduced later and sometimes are seen to be replacing felspar. In slide 7711M a large crystal of arsenopyrite is seen. It has moulded itself partly around a small felspar phenocryst, but it seems to be earlier than the groundmass felspars which are curved around it in a flowage structure.

No. 7708 is a slightly different variety, consisting of a few phenocrysts of oligoclase $AB_{87}An_{13}$ up to 1 mm. across and an occasional altered femic phenocryst, lying in a groundmass of orthoclase, oligoclase, chloritised femic material, abundant magnetite and calcite. The felspar laths of the groundmass are mainly orthoclase and are arranged in trachytic texture. The femic constituents (apart from a little unaltered augite) are always altered and partly resorbed. The remains of one large phenocryst 5 mm. long, probably originally of hornblende, are recognizable only by a concentration of iron ore, chlorite, and minute felspar prisms. Some of the secondary calcite is apparently of late introduction—a veinlet of that mineral traverses the slide.

Mineral Deposits

Within the area a large number of mineral lodes occur. About 80 have been mapped by Ferguson. These lodes occur exclusively within the granodiorite; none have been found in the Ordovician sediments or in the Snowy River Volcanics. The distribution of the lodes within the granodiorite reveals some features of interest. On the western, or down-thrown, block of the Turnback Fault, the lodes occur widely distributed throughout the granodiorite but increase in density as the fault is approached. On the eastern side of the fault, no lodes occur. It is therefore clear that the Turnback Fault has been the important structural feature governing the distribution of the lodes. (It will be recalled that almost exactly similar relations apply to the distribution of lamprophyres.) (See Fig. 2.)

The lodes possess two dominant strikes. The most important by far is a N.W.-N.N.W. strike. This is also the strike of the lamprophyres, and the Turnback Fault, and the principal strike of the latite dykes. It is interesting to note that as the Turnback Fault swings around from a N.N.W. strike towards a N.W. strike, the strike of lodes and dykes swings around so that they remain parallel to the fault.

The N.W. striking lodes are often very persistent, and can sometimes be traced for upwards of a mile. Another smaller set of lodes possesses a dominant E.-W. strike. These are typically short, and are restricted in occurrence to a long narrow zone of granodiorite close to the Turnback Fault. The significance of these structural relations will be discussed later.

The lodes occupy true fractures along which considerable movement has often taken place. Slickensides indicating horizontal movement are very common, although rarely they indicate vertical movement. The dip of the lodes is mostly vertical although divergence from this dip up to 20° often occurs. The thickness is very variable, ranging from a fraction of an inch up to 3 ft. Large variation of thickness may occur within a short distance. Sometimes a lode consists of one principal fracture, whilst at other times there may be a number of anastomosing mineralized fractures forming a stockwerke—as at the James Lode, in the northern tunnel.

The minerals which have been introduced comprise mainly quartz and galena, with lesser quantities of barite, calcite, sphalerite, pyrite, chalcopyrite and arsenopyrite. These minerals have been introduced into the fissures by the mineralizing solutions and have been deposited mainly by replacement of wall rock. (Slides 7713-7724.) Filling of open spaces has been of minor importance, although it is noticeable locally—e.g., a small offshoot of the United Lode has a large number of vughs and open spaces which have been partly filled by quartz, barite and galena.

The sulphide minerals occur in shoots, of which there is never more than one along any mineralized fracture. The shoots of ore are usually very narrow and irregular in width. In places, as at the James, United and Begelhole lodes, sulphides may be distributed through sheared granodiorite over a width of about 3 ft., and yet in a distance of only a few yards from such occurrences, the lodes may have thinned out to a few inches.

In places, the lodes contain bulges of massive galena up to a foot wide, but they are usually small. The largest bulge occurred at the Eastern Lode, where pure galena, 1 ft. wide, extended for 60 ft. Other rich pockets occur at the James and United Lodges, but they are much smaller. Wherever these bulges occur, there are practically no gangue minerals; however, in places where galena is disseminated through the sheared and altered granodiorite, large amounts of quartz are always present.

Wall Rock Alteration. The solutions which have carried the sulphides have altered the wall rock for distances from 2 ft. to 20 ft. from the fracture. The width

of the zone of alteration is closely connected with the amount and intensity of minor fracturing associated with the main fracture. The alteration is predominantly sericitisation of wall rock, followed by silicification.

The wall rock alteration may be conveniently divided into three zones.

Zone 1. For considerable distances on either side of the lode, sericitisation of andesine in the granodiorite has occurred, e.g. slide 7713 taken 20 ft. from the United Lode. Orthoclase and quartz are unaffected, but biotite is bleached and chloritised. Closer to the lode, orthoclase becomes kaolinised (slides 7714, 7715, 7716).

Zone 2. Immediately next to the lode, usually with a thickness of a few inches but occasionally up to 3 ft. wide, is a zone of intensely strong sericitisation. The partly kaolinised orthoclase is almost completely replaced by sericite. Andesine is completely sericitised, but relics of chloritised biotite remain (slides 7719, 7720). Secondary muscovite is developing in many places. The hand specimen (N7) is a characteristic soft greenish rock of granular texture with small visible flakes of muscovite.

Zone 3. This zone comprises the mineralized rock which constitutes the lode proper. It is characterized by the introduction of quartz and sulphides, and then subsequent replacement of the sericitised sheared granodiorite described in zone 2 (slides 7717, 7721). Slide 7717 displays well the selective replacement of sericite by galena. The permeability and large surface area of the sericite has probably caused galena from the mineralizing solutions to be precipitated by sericite more so than quartz. Slides 7717 and 7721 indicate that fracturing has occurred whilst deposition of quartz was taking place. Small veinlets of quartz cut sharply across the earlier generation of quartz which is replacing sericite. In slide 7721, galena occurs in the centre of the veinlet. In all slides where galena occurs in close association with quartz it is seen to be later than the quartz and replacing it.

Most students of ore deposition attribute the sericitisation of wall rock so common in mineral deposits to the effect of hot alkali bearing solutions which transported the sulphide minerals. Analyses usually indicate that large amounts of potash are added to the wall rock during the process of sericitisation. The fact that in the case just described, the andesine has been most susceptible to sericitisation, and not orthoclase, which is only sericitised at a much later stage, suggests that the solutions carried potash. Furthermore, the development of muscovite close to the lodes suggests that the sulphide bearing solutions were at a fairly high temperature (Lindgren, 1933).

The fact that kaolinite is one of the main alteration products indicates that the mineralizing solutions were of acidic character (Gruner, 1944). Since sericite has been formed (in the outer zone of alteration) at the same time as kaolin, it would seem that the solutions have not, however, been very strongly acidic.

In hot, slightly acidic environments, whether felspar alters to sericite or kaolinite is determined by the concentration of the potassium ion (Gruner, 1944). Since most of the orthoclase in the zone next to the lode has been sericitised, whilst further out the orthoclase has been kaolinised, it would appear that most of the potash introduced by the mineralizing solutions has been fixed in the sericitised country rock nearest to the lode. The alteration further out has been caused by solutions poorer in potash, which have therefore kaolinised the orthoclase. However, they must have contained some potash, since the andesine has been sericitised to a larger extent.

The Eastern Lode cuts a lamprophyre dyke. For some distance along the dyke on the north side of the intersection, the lamprophyre has been considerably altered. Quartz and galena have been deposited throughout the body of the rock, forming a low grade ore. The alteration is displayed in slides 7723 and 7724. The lamprophyre was evidently a mica bearing variety, since the chloritised remnants of numerous crystals of biotite are present. Apart from the biotite, the remainder of the rock has been altered to a fibrous aggregate of some micaceous mineral. This mineral possesses a high relief and forms small prisms averaging 0·1 mm. long. Its birefringence is low, resulting in a first order yellow. It is coloured pale green, possesses slight pleochroism, has a perfect cleavage, and is length slow. Antigorite is the mineral which fits this description best, but the high relief displayed by the mineral seems to rule antigorite out. Nevertheless, it is probably some other kind of chlorite or serpentine mineral.

It is being replaced by quartz, which occurs widely throughout the rock, both disseminated, and occupying fractures. Slide 7724 shows a further stage of replacement. Large euhedral crystals of quartz are replacing the antigorite (?), and moulded on to the hexagonal crystals of quartz, and enclosing some, is a large crystal of galena, which is clearly later than the quartz. The quartz crystals exhibit an interesting growth phenomenon (Plate III). At an intermediate stage of growth, a euhedral crystal of quartz has incorporated a border of inclusions. Previously, the quartz had been quite uniform. However, incorporation of these inclusions has altered the nature of the radial growth, giving it a radial comb structure, which nevertheless preserves a perfect hexagonal outline.

Paragenesis. The mineral assemblage of the lodes is limited. Galena is by far the most common sulphide mineral. Other sulphides present are sphalerite, chalcopyrite, pyrite and a minute amount of arsenopyrite.

A study of polished and thin sections indicates that the sulphides, together with gangue minerals, were deposited in a definite order, as follows:

Quartz
Period of Fracturing
Quartz
Pyrite, arsenopyrite
Sphalerite, chalcopyrite
Galena
Period of Fracturing
Pyrite

Apart from the late generation of pyrite, this sequence of deposition is the same as that occurring in most ore deposits.

The existence of the first period of fracturing is demonstrated in slides 7721 and 7717, where veinlets of quartz cut other quartz which is replacing sericite. The existence of a second period of fracturing is indicated in polished section No. 1. Veinlets of pyrite are observed to cut galena and sphalerite.

In the polished section examined, chalcopyrite occurred in small amounts as exsolution bodies in one of the specimens of sphalerite. The other specimens contained no chalcopyrite. This mineral, however, occurs in massive form at the Begelhole Lode, associated with galena and sphalerite.

Temperature of Deposition. The existence of numerous ex-solution blebs of chalcopyrite distributed randomly throughout some of the sphalerite from the United Lode furnishes a valuable criterion of deposition temperatures. Since solid

solution of chalcopyrite in sphalerite only occurs above 350°-400° C. in appreciable amounts, the above temperatures are the minimum temperatures at which the sphalerite was deposited.

Considering their geological situation, the depth of deposition of the ores would almost certainly be less than 15,000 ft., allowing for the probability of 10,000 ft. of volcanics, 3,000 ft. of Buchan Limestone, and a couple of thousand feet of Upper Devonian sediments overlay the granodiorite at the time of deposition. Assuming a normal thermal gradient the temperature at this depth would be about 160° C. It is therefore clear that the mineralizing solutions have been derived from a source which was considerably warmer than the surrounding country rock. An igneous source would therefore seem to be necessary.

Relations of Lodes and Dykes. Actually there is ample field and mineralogical evidence which strongly suggests that the process of ore deposition was intimately connected with the lamprophyre dykes. The evidence for genetic association of ore deposits with these dykes may be briefly stated.

(i) The ore deposits and dykes are closely connected in time. Both are very probably post Middle Devonian, and were emplaced before the conclusion of the Tabberabberan Orogeny (see later section). The lodes are later than the dykes, transgressing them at intersections.

(ii) Dykes and lodes exhibit a regional association. At Deddick there is a close spatial connection. Farther south in the granite at Campbell's Nob, the author has found similar lamprophyres in close relation to galena bearing lodes. In the limestones at Buchan and Murrindal, Howitt has described deposits of galena which have formed along and close to similar lamprophyres which intrude the Middle Devonian Limestones. The area between Deddick and Buchan seems to constitute a mineral province characterized by lead mineralization and lamprophyre dykes.

(iii) Dykes and ore deposits at Deddick show a close structural relation. They occupy the same system of fractures controlled by the Turnback Fault—some fractures being taken by dykes and others by lodes. Sometimes lodes form along dykes. To quote Ferguson (1899), who fully recognized this relationship, "where there are most dykes, there are most lodes".

(iv) The dykes commonly carry small quantities of sulphides, principally pyrite, chalcopyrite and arsenopyrite, distributed throughout their bulk. In some cases, these appear to be primary minerals, e.g. the arsenopyrite in section M5 which has crystallized around a phenocryst of felspar but which nevertheless appears to be earlier than the groundmass felspars which are arranged about it as in typical flow textures. Furthermore, in the Campbell's Nob dykes, small patches of galena are widely distributed throughout the dykes. The widespread occurrence of small quantities of sulphides in the dykes is suggestive of a close genetic relation between dykes and lodes.

(v) It was shown previously that the mineralizing solutions deposited sphalerite at a temperature greater than 350° C. It was also shown that the country rock was at a temperature probably less than 160° C. The high temperature of the mineralizing solutions appears to indicate that they were derived from some igneous agency, which according to field evidence could only be the lamprophyric magma.

Regional Metamorphism of Galena. It was maintained above that the formation of galena lodes preceded the Tabberabberan Orogeny, which was responsible for the widespread and intense fracturing of granodiorite and lamprophyre dykes, and the folding of the Snowy River Volcanics. The evidence for this asser-

tion lies in the fact that the galena at Deddick is invariably found to have suffered plastic deformation. Usually the deformation is not intense, giving rise to curved and distorted cleavage planes which are universal (HS nos. P1, P2). The plastic flow is sometimes well exhibited in the polished sections, where it is shown up by curving lines of cleavage pits in the galena. Sometimes a distinct banded texture due to plastic flow has arisen (HS nos. P1, P2). This widespread regional metamorphism of the galena is to be correlated with the widespread tectonic stresses developed during the Tabberabberan Orogeny.

Silver Content of Galena. A number of polished galena specimens were examined in order to determine the form in which the silver occurred. No trace of any silver bearing mineral (e.g. Tetrahedrite) was found, and it was concluded that the silver is carried in solid solution in the galena. Four tons of ore taken from various parts of the field when sampled and assayed at Port Pirie were found to contain 50·9% .Pb, 4·3% Zn and 15·8 oz/ton Ag. This corresponds to 27 oz. silver per ton of galena. Galena can carry up to 30 oz. to the ton of silver in solid solution (Edwards, 1947) and hence the Deddick galena must carry its silver in that form.

Oxidation. The mineral deposits possess very small zones of oxidation. In many places fresh galena occurs right at the surface. However, at the James and United Lodes, relatively small amounts of anglesite and cerrussite occur, whilst malachite and azurite are common in the Begelhole Lode. The smallness of the zones of oxidation is to be attributed to the extremely rapid dissection which the area is undergoing.

Mineral Zoning. An interesting feature of the mineral deposits is that mineral zoning is often well displayed, although the shoots of sulphide minerals possess only relatively small vertical depth ranges. The mineral zoning cannot be followed continuously, since the lodes have not been opened up by mining operations to any extent. However, in certain of the lodes which outcrop down very steep hillsides, and which have been opened up by cuts and adits at frequent intervals, the zoning can be recognized.

The best example is the Begelhole Lode. About 600 ft. above the river, a shaft follows the lode down for 50 ft. The sulphides here consist of pure galena. Some 300 ft. lower, an adit just above the road cuts the lode which consists of galena, with some massive chalcopyrite. Below the road, about 100 ft. above the river, another two adits show the lode to consist of a complex ore of sphalerite, chalcopyrite, pyrite and galena. On the opposite bank of the river, at the Mt. Deddick Mine, on the same lode, a shaft put down for 50 ft. encountered lode material rich in pyrite, together with some galena.

A vertical section of this lode consists of:

Galena
Chalcopyrite and galena
Chalcopyrite sphalerite and galena
Pyrite and galena.

This is in accord with the normal order of mineral zoning as given by Emmons (1924). Galena in depth tends to give way to chalcopyrite. Deeper still sphalerite comes in, and the deepest zone is mainly of pyrite. It should be pointed out, however, that galena is present in large amounts at all levels.

Another lode displaying zoning is the United, which outcrops down a very steep hillside At the top it consists of a quartz reef carrying small quantities of sulphides. Thirty feet lower this makes into a bulge of pure massive galena, and

further down for another hundred feet, sphalerite begins to come in, increasing towards the bottom adit, where it is almost as abundant as galena.

The other lode displaying zoning is the James. The uppermost cuts show this lode to consist of quartz carrying some galena. One hundred feet lower down the lode consists of massive galena, and then for another 200 ft., although galena is by far the most common mineral, small amounts of sphalerite and chalcopyrite occur. Another 50 ft. lower, the lode consists of sheared granodiorite feebly mineralized with pyrite.

The lodes mentioned above are the only ones which have been appreciably exposed, and in each of them, vertical mineral zoning is displayed within a limited vertical extent of a maximum of 600 ft. in the case of the Begelhole Lode. There is no sign of a corresponding horizontal mineral zoning about any defined centre, however.

ECONOMIC POSSIBILITIES. There are two shoots of high-grade galena exposed in the James and United Lodes which might repay mining by a small syndicate. However, the main obstacle would be transport difficulties. The mines, although only 3 miles from a road (1½ miles directly across the Snowy River) are situated in rugged and inaccessible country. The value of the ore shoots may be insufficient to justify making a road in. Apart from the lodes mentioned none of the deposits opened up so far appears to be worth any attention. Any further work should be limited to the prospecting of gossans which have not as yet been opened up. Several of these have been noticed by the author.

STRUCTURAL RELATIONS OF LODES AND DYKES

The major features of the distribution of lodes and dykes have already been described (page , Fig. 2). Briefly these are:

(i) Dominant NW-NNW strike of both lodes and dykes. The strike is parallel to that of the Turnback Fault.

(ii) Concentration of lodes and dykes along a narrow zone south-west of the Turnback Fault. Lodes and dykes are absent on the other side of the fault. Density of lodes and dykes dies away gradually towards the south-west of the fault.

(iii) Occurrence in the zone nearest the fault of a series of E-W striking lodes, characteristically short, forming a set of complementary shears to the main N-W shear direction.

The significance of these facts must now be discussed. The fact that all the lodes and dykes occur in the down-thrown block south-west of the Turnback Fault, and that they increase in density as the fault is approached from the south-west, shows clearly that the fracture pattern of lodes and dykes has been controlled by the fault.

An hypothesis which seems at first sight attractive is that the dyke and lode fractures have been formed at the same time and by the same causes as the Turnback Fault, which is of Lower Devonian age. Subsequently, during the Upper Devonian, the fractures have been filled by dykes and lodes. Such an hypothesis is suggested by the exact parallelism of most dykes and lodes with the arcuate fault, the increase in density of dykes and lodes close to the fault, and by their dominant vertical dips. These fractures would therefore be regarded as subsidiary faults which have been partly responsible for sinking of the down-thrown block. There are two facts, however, which invalidate this hypothesis. The formation of complementary E-W shears close to the fault is not explained. It will be recalled

that the dips of both sets of shears are close to vertical, and therefore the direction of the stress which caused the fracture pattern must have lain in the horizontal plane. According to the hypothesis mentioned above, the stress would lie mainly in the vertical plane. Furthermore, it would be expected that the direction of movement along these fractures would be vertical, whereas the great majority of slickensides indicate horizontal movement, a fact which was noticed by Ferguson (1899).

Two interpretations of the evidence are possible. The Turnback Fault might be regarded as having behaved as a surface of weakness in the stressed medium. In this case, the stress is to be regarded as normal, and according to the strain ellipsoid (Fig. 2) due to compression from the north-west, making an angle of about 25° with the Turnback Fault. The result has been the building up of a maximum amount of stress near the fault, causing greater intensity of shearing in the two complementary directions. Away from the fault the stress has been less, resulting in smaller fracture density and the suppression of one of the shear directions. It is probably because of the low angle of incidence (25°) of the plane of maximum stress with the plane of weakness in the granodiorite that the effects of the stress have not been manifested on the other side of the fault sufficiently to cause rupture.

An alternative interpretation would be to regard the fracture pattern as due to shearing stress in the horizontal plane developed along the Turnback Fault. This explains the more intense shearing close to the fault and the suppression of one of the directions of shear farther away. It does not, however, account satisfactorily for the complete absence of shearing north-east of the fault.

CAINOZOIC–(PLIOCENE?)

Fluviatile Deposits

Small patches of river gravels and sands occur beneath the basalt near the 8-mile post on the Deddick road, and on Mt. Turnback. Ferguson reports finding some thin interbedded clays containing leaf impressions. These gravels do not appear to be more than 20-30 ft. thick. They are not found beneath the basalt at Wulgulmerang. Their physiographic significance has already been commented upon.

Newer Basalt

Basalt occurs on the plateau between the Buchan and Snowy Rivers in the central part of the Wulgulmerang area. A second large flow occurs at Gelantipy, stretching towards the south. It was formerly continuous with the Wulgulmerang sheet, but has now been separated due to dissection by Boundary Creek and its tributaries. A couple of small isolated outcrops at the same height (2,800-3,000 ft.) occur towards Black Mountain. These basalts are apparently the remains of a much more extensive sheet which sloped gently towards the south. The N-S ridge forming the Buchan River divide lies at a higher elevation than the basalt and marks the western limit towards which the flow originally extended. There is no such continuous containing ridge to the east, unless it is on the opposite side of the Snowy River. However, isolated inliers of rhyodacite protrude through the basalt quite frequently. The basalt at Wulgulmerang is usually less than 100 ft. in thickness, although it is thicker at Gelantipy. (See section in physiography.)

Small patches of basalt occurring at the Farm, Mt. Turnback and the 8-mile post are about 1,000 ft. lower than the Wulgulmerang flow. These are probably remnants of a formerly continuous flow which came down the Snowy River valley during an early stage of dissection, after the Pliocene uplift. The occurrence of river gravels underlying some of these basalts supports this interpretation.

The fact that the Wulgulmerang and Gelantipy basalts still cover considerable areas, and lie at a lower elevation than remnants of the pre-basaltic peneplain led Hills (1938) to group them with the Newer Basalts. He suggested, however, that in view of the large amount of erosion by the Snowy River subsequent to their extrusion they must be among the oldest of the Newer Basalts—possibly of Pliocene age. The fact that similar basalt has been extruded at an intermediate stage of dissection by the Snowy River, at an elevation of 1,000 ft. lower than the Wulgulmerang basalts, supports this thesis. On physiographical grounds the second flow of basalt must certainly belong to the Newer Basalt.

A slide (No. 7725) from Mt. Turnback indicates that the basalt is a coarse-grained olivine bearing variety. Laths of acid labradorite $Ab_{48}An_{52}$ up to 1 mm. long, subhedral crystals of augite, and subhedral olivine, together with a large amount of interstitial glass extremely rich in magnetite make up the rock.

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Description of Plates

Plate II

Aerial photograph of granodiorite – rhyodacite contact near the Little River. Height 17,000 ft.

Plate III

Fig. 1.—Deddick Rhyodacite (Porphyritic). 1. Quartz. 2. Albite. 3. Bleached Biotite. × 12.

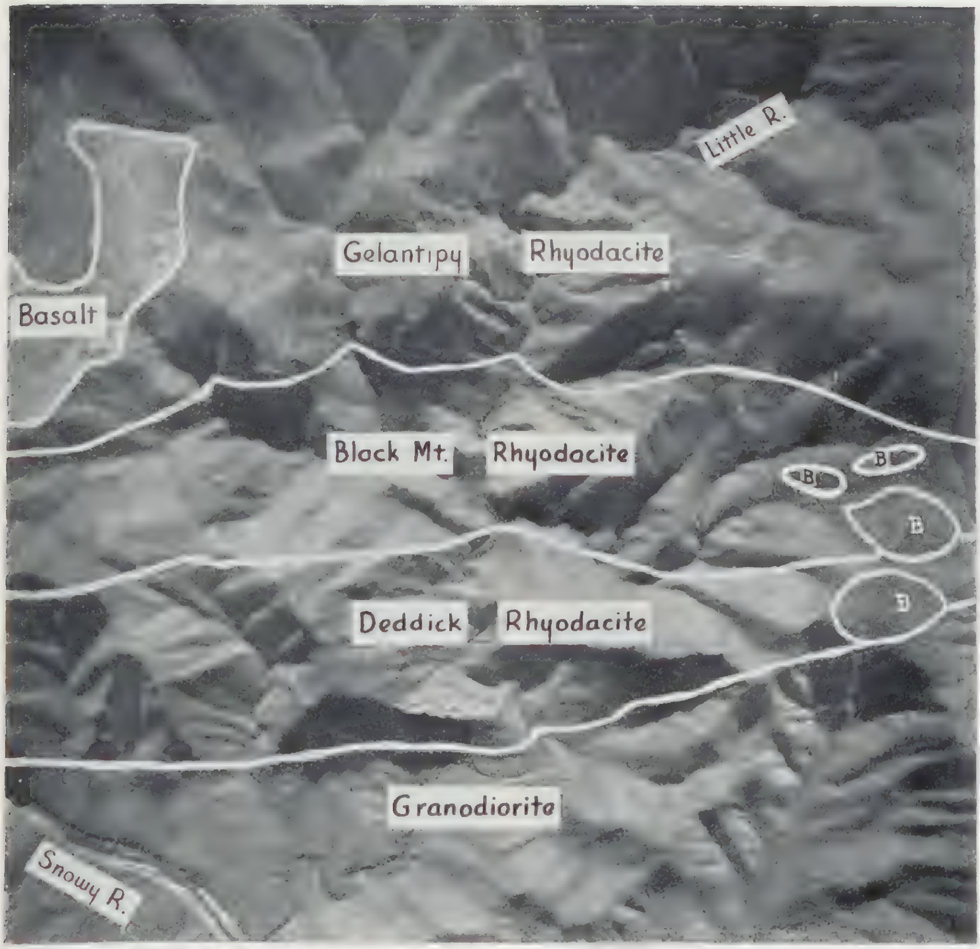
Fig. 2.—Black Mountain Rhyodacite. 1. Quartz. 2. Albitised andesine. × 12.

Fig. 3.—Gelantipy Rhyodacite. 1. Quartz. 2. Albite. Flow structure displayed. × 12.

Fig. 4.—Garnet in Granodiorite, showing reaction rim. 1. Garnet (Almandine). 2. Magnetite. 3. Pinitised Cordierite. 4. Biotite. 5. Granodiorite. × 12.

Fig. 5.—Biotite Monchiquite, showing magnetite-pyroxene intergrowth with pyroxene reaction rim. 1. Magnetite-pyroxene intergrowth. 2. Pyroxene reaction rim. 3. Groundmass, consisting of pyroxene, olivine, magnetite and glass. × 72.

Fig. 6.—Mineralized Lamprophyre replaced by galena and euhedral quartz. Growth of quartz crystals has been modified by impurities. 1. Altered Lamprophyre (antigorite?). 2. Galena. 3. Quartz. 4. Impurities in quartz giving rise to comb structure. × 12.


Little R.
Gelantipy
Rhyodacite
Basalt
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Deddick
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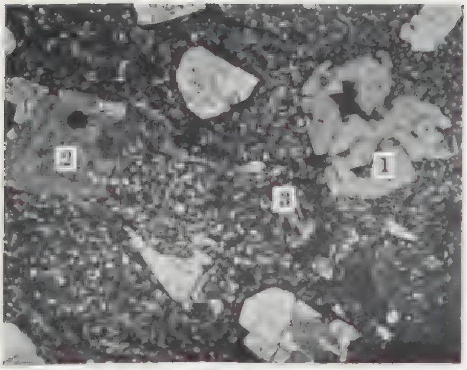
Granodiorite
Snowy R.



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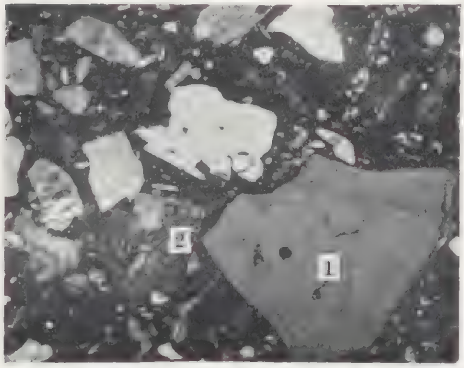

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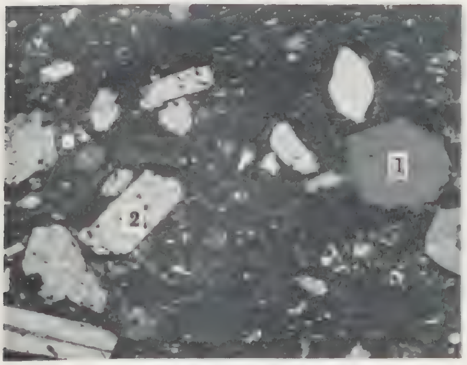

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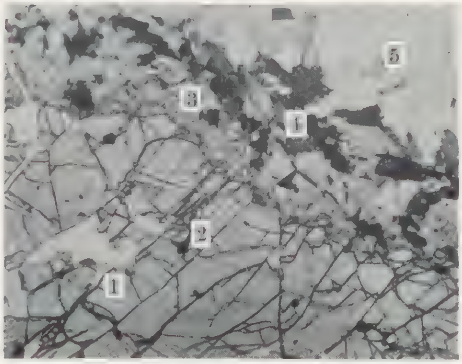

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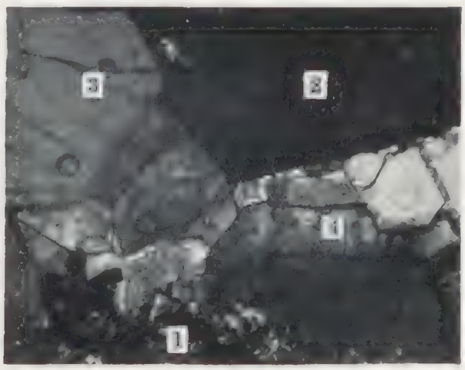

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4

THE GEOLOGY OF THE SNOWY RIVER DISTRICT, EAST GIPPSLAND

By A. E. Ringwood, M.Sc.

[Read 10 June 1954]

Introduction

This paper has been prepared to supplement an earlier paper by the author in this journal covering the geology of 180 square miles of the Deddick and Wulgulmerang area. In that paper, among other subjects, the stratigraphy, petrology and structural relationships of the Snowy River Volcanics were discussed in some detail. This contribution describes the results of additional reconnaissance mapping undertaken to reveal the regional stratigraphic and structural relationships of the Snowy River Volcanics. The area covered stretches from The Cobberas in the north to Murrindal in the south, a distance of 40 miles, and lies parallel to, and partly along, the Snowy River.

The mapping has been based upon field mapping by Ferguson for the Geological Survey, in which the boundaries of major formations were outlined. The work of the author has consisted principally in mapping the individual flows within the Snowy River Volcanics. The Snowy River Volcanics south of Murrindal have already been the subject of work by Teale (1920), Cochrane and Samson (1947) and Gaskin (unpublished), and correlation between these areas and the district to the north has been obtained.

Previous Work

In the earlier paper the author has discussed most of the previous work pertaining to the area covered. The reader is referred to that paper for details. The various papers mentioned will be considered when they are relevant to the context. The only one not mentioned previously is a brief report by Ferguson (1899A) on the Geological Survey of the Snowy River.

The only work of importance previously carried out in the area has been by Howitt (1876, 1878) and Ferguson (1899B).

Physiography

The physiography of the area is controlled by the differential erosion of an elevated peneplain. The peneplain, partly covered by Newer Basalt, slopes regularly down from The Cobberas (6,025 ft.) towards the south. It is in a youthful stage of dissection and the main rivers and creeks have incised gorges and steep-sided valleys.

Granitic rocks and limestones have been much less resistant to erosion than the slates and volcanics and tend to occur in topographic basins surrounded by high rugged slate and rhyodacite country. Basins of this kind in granitic rocks are found at Deddick, Suggan Buggan, Campbell's Nob and along the Buchan River. Basins in limestone country include Murrindal, Native Dog Creek and Gelantipy. Wherever volcanics and slates are dissected, great gorges and precipitous valleys are formed—e.g., Little River, Boundary Creek, and the Snowy

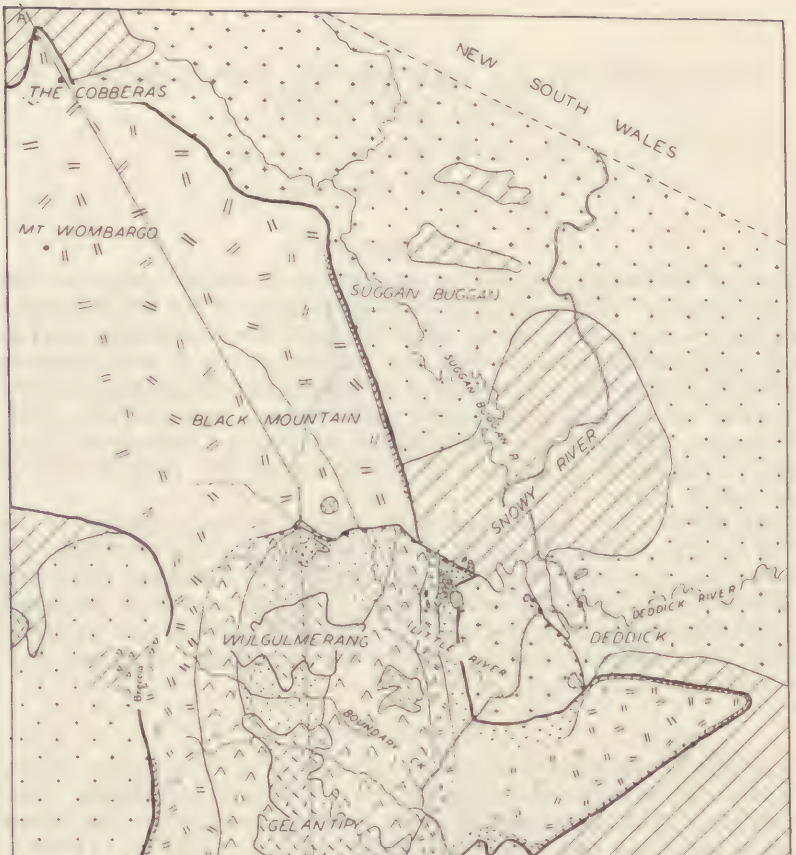
A
THE COBBERAS
NEW SOUTH WALES
MT WOMBARGO
SUGGAN BUGGAN
SUGGAN BUGGAN R
SNOWY RIVER
BLACK MOUNTAIN
DEDDICK RIVER
DEDDICK
WULGULMERANG
LITTLE RIVER
Breccia
BOUNDARY CK
GELANTIPY
CAMPBELLS NOB
MURRINDAL R
BUTCHERS RIDGE
BUTCHERS CK
TREE
BUCHAN RIVER
B
MURRINDAL
LEGEND
BASALT
ALLUVIAL
CAINOZOIC
LIMESTONE
MIDDLE DEVONIAN
LATITE
FRAGMENTAL
GELANTIPY RHYODACITE
BLACK MT RHYODACITE
DEDDICK RHYODACITE
LOWER DEVONIAN
GRANODIORITE
ORDOVICIAN
FAULT
ROAD
N
SCALE OF MILES

FIG. 1.

River Gorges. These commonly have walls over 2,000 ft. sheer, and furnish magnificent scenery.

Uplift of the peneplain probably took place in the Pliocene, following extrusion of basalt. The pre-basaltic peneplain is well developed around Wulgulmerang, Deddick, and farther north, and had suffered little dissection at the time the basalt was extruded. However, dissection of the pre-basaltic surface becomes more marked as one proceeds southwards, local relief at Gelantipy being of the order of 500 ft.

General Geology

Upper Ordovician

Sediments of this age are widespread. The largest exposures occur to the east of the Snowy River and south of the Deddick River, where Upper Ordovician sediments either outcrop or underlie the volcanics. Another large exposure occurs along the Snowy River north of McKellop's Crossing. Other occurrences are near The Cobberas and along the Buchan River west of Wulgulmerang.

The sediments consist of sandstones, greywackes, mudstones, shales and slates which are sometimes carbonaceous. They have been folded and subsequently invaded by intrusions of granite rocks mainly granodiorites, giving rise to contact aureoles of low to medium grade hornfels.

Granitic Rocks

Large exposures of granitic rocks occur in the north of the area and also along the Buchan River. These outcrops are probably continuous beneath the Snowy River Volcanics and form part of the Corryong Batholith (Edwards and Easton 1937) and are also to be correlated with the "grey granites and granodiorites" of Crohn (1949).

Petrological examination has been confined to the rocks of the Deddick district, and it has been shown that they vary between granite and granodiorites in composition, with all gradations between the two. Mostly, however, those with granodioritic or adamellitic composition appear to predominate. An interesting feature of the rock is the common occurrence of cordierite in crystals up to 5 mm. across.

Wherever observed, the granitic rocks are intensely shattered by tectonic movements. The intrusions are broken into small blocks by closely spaced joints and fractures. Slickensides are abundant. No gneissic textures are developed, however. It was shown in the previous paper that this widespread shattering was probably caused by the Tabberabberan Orogeny which folded the overlying Snowy River Volcanics and Buchan Limestones. It was further suggested that the mechanism of folding involved large net vertical movements of the granodiorite by means of a giant fault-folding effect, accompanied by the development of normal anticlines and synclines in the overlying volcanics and limestones.

The granodiorite intrudes Upper Ordovician sediments and underlies unconformably the Snowy River Volcanics of Lower Devonian age. In view of the considerable length of time required to expose the batholith by erosion, prior to the extrusion of volcanics, it seems likely that the granitic rocks are of Silurian age.

Lower Devonian

A large part of the area to the west of the Snowy River is occupied by the Snowy River Volcanics, which consist of extrusive rhyodacites, latites, and fragmental rocks. Howitt (1876) showed that they overlie the granodiorite and Ordovician sediments unconformably and underlie conformably the Buchan Limestones

of Middle Devonian age. Accordingly he suggested that the Snowy River Volcanics were of Lower Devonian age. Subsequent palaeontological work has established that the basal members of the Buchan Limestones belong to a horizon low in the Middle Devonian and hence Howitt's estimate would appear to be correct. Indeed, in view of the great thickness of the volcanics and the frequent interruptions in the vulcanism indicated by numerous beds of intercalated sediments it would appear that the formation of the Snowy River Volcanics must have occupied a considerable period of time. Perhaps, therefore, some of the early flows may be of Upper Silurian age.

At Deddick, a sequence of members of the Snowy River Volcanics has been determined. For the present purpose, a somewhat simplified sequence will be used, involving only the most important members. Accordingly the Snowy River Volcanics may be subdivided thus.

Latite
Fragmental Rocks { Wulgulmerang Tuffs / Boundary Creek Conglomerates }
Gelantipy Rhyodacite
Black Mountain Rhyodacite
Deddick Rhyodacite

The petrology of these rocks has already been described and there seems little point in repeating the descriptions. It may be noted, however, that the three rhyodacites are very similar chemically. All three are quartz rich rhyodacites which have suffered extensive secondary alteration—mainly albitization. They are to be differentiated and recognized according to their textural features, both microscopic and macroscopic. A summary of these in tabular fashion appears in the earlier paper.

Deddick Rhyodacites

These constitute the basal members of the Snowy River Volcanics. They are widespread in the Deddick-Wulgulmerang area and attain their maximum thickness of about 3,100 ft. in the Little River district, south of the Turnback Fault. The flows thin out in all directions outwards from Little River. To the east, in the Deddick area, the thicknesses range from 200 to 1,000 ft., whilst northwards towards Suggan Buggan the total thickness is only 200 ft. Near the Buchan River west of Butcher's Ridge a thickness of about 200 ft. of Deddick Rhyodacite outcrops between the granodiorite and the overlying Black Mountain Rhyodacite. There are two varieties of Deddick Rhyodacite—fine-grained and porphyritic. The latter are found only in the Little River and Deddick areas. Numerous interbedded flows of these types occur at Little River together with intercalated lenses of sedimentary rocks mainly conglomerates.

The Deddick Rhyodacite is probably continuous at the base of the Snowy River Volcanics over most of the area. When it is not found at the contact of the volcanics and basement work the reason is usually faulting, as at Seldom Seen and Wheeler's Creek.

Black Mountain Rhyodacite

Overlying the Deddick Rhyodacite is a flow of great thickness and extent which has been called the Black Mountain Rhyodacite. This is a coarsely porphyritic rhyodacite, densely packed with phenocrysts, and varying between red and black in colour. It attains a thickness of 2,500 ft. in the Little River Gorge and this thickness is probably exceeded along the Buchan River Divide. The whole

of the plateau north of Wulgulmerang, stretching to The Cobberas, is composed of this flow (apart from small occurrences of fragmental rocks near The Cobberas, Black Mountain and Omeo Hill). To the south, it outcrops in two parallel belts forming the limbs of a syncline. One limb outcrops in the range stretching southwards from Mt. Wombargo–Mt. Statham–Mt. Murrindal, whilst the other limb can be traced southwards past Campbell's Nob. It has not been located south of Talicard, however, since it probably outcrops farther to the east in unmapped and inaccessible country. However, this limb is again picked up a couple of miles north of Murrindal where it underlies the limestone.

On the east side of the Snowy River the whole plateau from Deddick in the west to Accommodation Creek in the east, and southwards to Campbell's Nob, is of Black Mountain Rhyodacite. Opposite Butcher's Ridge, on the Buchan River Divide, a flow of latite a few hundred feet thick occurs intercalated with the Black Mountain Rhyodacite not far from the base. Farther south between Murrindal and Buchan, flows of latite become more common, but still appear to be associated with the Black Mountain Rhyodacite (Gaskin: personal communication).

Gelantipy Rhyodacite

The flow which overlies the Black Mountain Rhyodacite is also of great thickness and extent. In the Little River Gorge it is about 2,700 ft. thick. It maintains and probably increases this thickness towards the south. However, it is not found in the northern part of this area, ending abruptly at the Turnback Fault. The significance of this structure was discussed in the previous paper.

At Wulgulmerang the Gelantipy Rhyodacite outcrops in two parallel bands striking north-south; one near the Buchan Divide and one in the Little River-Farm area. These outcrops dip inwards and form a synclinal structure. Towards the south the outcrops converge at Gelantipy, thus forming a basin-shaped structure open at the northern end. It then extends continuously southwards occupying the core of a syncline to a locality between W-tree and Murrindal, where it dies out. Intercalated in the Gelantipy Rhyodacite beds of fragmental material, mainly tuffs, together with some conglomerates, are found. Howitt (1878) has described some sandstones and arkoses occurring near the top of the Gelantipy Rhyodacite at Butcher's Creek. These intercalated beds of fragmental rocks are usually only of local importance and their extent is generally very limited.

Petrologically the Gelantipy Rhyodacite is very similar to the Black Mountain Rhyodacite. The phenocrysts, however, are smaller, sparser, and more euhedral in form. Unlike the Black Mountain Rhyodacite, its appearance is very easily altered by weathering which gives rise to products of the most varied textures and colours. This often makes it difficult to recognize and identify hand specimens without considerable experience.

Fragmental Rocks

In the Deddick district, fragmental rocks occur at several horizons interbedded with the extrusive members. The only place where they are really well developed, however, is in the Wulgulmerang area, where conglomerates overlain by tuffs reach a thickness of 2,000 ft. They overlie the Gelantipy Rhyodacites and occupy a basin-shaped structure, being cut off to the north by the Turnback Fault, and dying out towards the south at Gelantipy. The conglomerates are formed almost exclusively of partly rounded rhyodacite pebbles. Most of the pebbles are of Gelantipy Rhyodacite. They have been called "Boundary Creek Conglomerates". The overlying tuffs have been designated the "Wulgulmerang Tuffs".

Near the base of the Snowy River Volcanics, interbedded mainly with Deddick Rhyodacite, several beds of conglomerate together with a small amount of tuffaceous mudstones and sandstones occur. The beds are usually less than 50 ft. thick. However, the pebbles and detritus are almost completely derived from Ordovician sandstones, greywackes and shales. Similar rocks have been described by Howitt (1878) from Butcher's Creek.

Latites

A flow of latite is the youngest member of the Snowy River Volcanics. It overlies the tuffs near the Turnback Fault, and occupies about one square mile. Two smaller and thinner flows occur at lower horizons in the Snowy River Volcanics.

As was mentioned earlier, a flow of latite occurs west of Butcher's Ridge near the base of the Black Mountain Rhyodacite. Latites related in time to this flow appear to become more common towards the south, between Murrindal and Buchan.

Middle Devonian

Howitt (1876, 1878) showed that the Buchan Limestones which were placed in the Middle Devonian on palaeontological grounds conformably overlay the "Snowy River Porphyries" in several places. At some places, a transitional series of calcareous tuffs occurred between the "porphyries" and the limestone, whilst at others, limestone rested on porphyry without any transitional beds. Howitt also discovered several instances where the limestone-porphyry contacts were faults.

Subsequently Gaskin (unpublished) has mapped the Snowy River Volcanics between Buchan and Murrindal. He has established that the limestones occupy the core of a large N-S striking synclinal fold in the volcanics. These relationships are not affected by the fact that limestone-volcanic contacts are sometimes faulted. The faults are usually local, and limited in extent.

North of Murrindal, five small outliers of limestone occur between W-Tree and Gelantipy. All five outcrops lie on the main synclinal axis stretching between Murrindal and Wulgulmerang; i.e. their geological relationships are similar to those of the Buchan Limestones. The dips of these outliers are low, and as far as could be ascertained, conform to those of the underlying volcanics. There can be little doubt that they represent the remnants of a formerly extensive limestone formation which conformably overlay the Snowy River Volcanics. Other outcrops also occur farther north at Native Dog Creek, The Pilot, and Limestone Creek.

The two northernmost outcrops rest directly upon Gelantipy Rhyodacite, but the outcrops near W-Tree are separated from the Gelantipy Rhyodacite by beds of fragmental rocks. Howitt (1878) has suggested that the limestones at W-Tree owe their position to faulting, but field evidence of this is lacking. In view of their general field relationships it seems most unlikely.

Structural Relationships

The mechanics of extrusion of the volcanics were discussed at length in the previous paper, and the matter will not be further pursued.

In that paper it was shown that the Snowy River Volcanics had been folded into north-south synclines and anticlines during the Tabberabberan Orogeny.

The sections and maps accompanying that paper display the structural relationships of that area. In Fig. 1 it is shown that the syncline occurring in the Snowy River Volcanics at Wulgulmerang continues southwards until it meets the syncline found by Gaskin in the Murrindal-Buchan district. It is suggested that a serviceable

name for this structure would be the "Murrindal Syncline". The limestones, as was mentioned earlier, lie folded in along the synclinal axis.

At Deddick, ten miles to the east of Wulgulmerang, a second synclinal structure striking approximately north-south occurs, in the rhyodacites. If the syncline is continued along the strike parallel to the Murrindal Syncline, it coincides with a long narrow infolded strip of limestone extending from the Snowy River east of W-Tree past Jackson's Crossing, and with interruptions to the "Basin" ten miles north-east of Buchan. At the Basin, Gaskin (personal communication) has established that the limestones also occur in the core of a syncline in the Snowy River Volcanics. It would therefore appear that a second major syncline exists, stretching from Deddick to the Buchan district, parallel to, and east of the Murrindal Syncline.

Ten miles to the west of the Murrindal Syncline, outcrops of limestone occur along an approximate north-south strike, namely at Limestone Creek, Native Dog Creek and Gellingall. In addition, between the two last-mentioned localities, Mr. Keith Rogers, a local resident who is a keen and reliable observer of geological phenomena, reports the existence of two hitherto unrecorded outcrops of limestone. Both lie approximately on the same strike. One patch is on the east side of the Buchan River opposite Seldom Seen Lookout, and the other is several miles to the south. It would therefore appear that a third north-south striking major synclinal structure is indicated.

Thus a broad picture of the structural geology of this part of East Gippsland begins to emerge. During the Lower Devonian epoch, great volumes of mainly acidic extrusives were erupted, covering possibly as much as two or three thousand square miles. The thickness of the volcanics reached 10,000 ft. in places. Regional subsidence then occurred during the Middle Devonian accompanied by deposition of a few thousand feet of marine limestone conformably overlying the volcanics. Finally, during Epi-Middle Devonian times, during the Tabberabberan Orogeny, the volcanics were folded into three major synclines separated by anticlines, all with an approximate north-south strike. The folds are probably continuous from the New South Wales border to Nowa Nowa. The more competent rhyodacites formed broad open folds whereas the limestones and tuffs were disharmonically folded within the major folds.

A long period of erosion then occurred during which most of the limestones were removed. The remaining limestones occur as isolated outliers in the cores of the synclines.

Epi-Middle Devonian

A swarm of lamprophyre dykes associated with silver-lead mineralization occur widely throughout the area. Mostly they are found in the basement granodiorite, as at Deddick and Campbell's Nob, but also rarely in the Snowy River Volcanics and overlying limestones (Howitt, 1878). They have been fully described in the earlier paper. The dykes are later than the Middle Devonian limestones but have been sheared and fractured, probably during later stages of the Tabberabberan Orogeny. The area dealt with appears to constitute a mineral province characterized by silver-lead mineralization associated with these dykes.

Cainozoic

A capping of Newer Basalt of probable Pliocene age (Hills, 1938) occurs on the Gelantipy Plateau between Wulgulmerang and W-Tree. The basalts appear to average about 200 ft. in thickness although locally they may reach 500 ft.

Acknowledgements

The author desires to express his appreciation for the advice and assistance of members of the Geology School, University of Melbourne, particularly to Professor E. S. Hills, under whose supervision the work was carried out, and Mr. A. J. Gaskin for much helpful discussion and permission to quote some of his unpublished results.

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STRATIGRAPHY OF TERTIARY ROCKS BETWEEN TORQUAY AND EASTERN VIEW, VICTORIA

By H. G. RAGGATT, D.SC., and IRENE CRESPIN, B.A., F.R.M.S.

[Read 8 July 1954]

Contents

Purpose and Scope of Investigation

For many years one of us (I.C.) has been examining the micro-faunas of the Tertiary beds of East Gippsland. In this region a considerable number of bores, and a shaft 10 ft. in diameter and 1,214 ft. deep, have provided samples through the complete local Tertiary sequence. As a result certain criteria for recognizing the sub-divisions of the Tertiary have been established, based on the micro-fauna (Crespin, 1941, 1943). The primary objective of the investigation described in this paper was to compare the faunas of the Tertiary of East Gippsland with those of the type sections of the "Anglesean" and "Janjukian" Stages (Hall and Pritchard, 1902, Singleton, 1941). Almost immediately the investigation commenced, however, it was found that the desired result could be achieved only by a detailed examination of the stratigraphy of the beds at the type localities for these Stages.

Casual examination and partial sampling of the Anglesea section revealed a considerable thickness of *Cyclammina*-bearing beds, where the late Dr. F. A. Singleton (1941, p. 25) had reported "unfossiliferous white sands". Examination of the section north of Point Addis and between Point Addis and Rocky Point showed that the relationship of the "Anglesean" to the "Janjukian" was revealed in outcrop and that errors had been made in correlating the beds exposed in different parts of the cliff sections between Rocky Point and Torquay. Sampling of the beds included in the uppermost "Janjukian" at Point Addis indicated a foraminiferal content more closely related to the "Balcombian" than to the "Janjukian". It was concluded that systematic measuring and sampling of the coastal sections between Torquay and Eastern View would enable the "Anglesean" and "Janjukian" to be adequately described (and perhaps re-defined) and their relationship to each other determined, and that it would also provide an opportunity to prepare a list of foraminifera in those units at the type localities.

Accordingly, every accessible exposure on the cliffs in these localities was examined, selected sections were measured and sampled, and the foraminifera in them identified. Correlation between the sections was made as carefully as the conditions permitted. In some places, as notably from Bird Rock westwards, several distinct markers were identified, enabling good control of correlation to be maintained.

During the investigation, cliff sections were examined from Point Danger to Eastern View, a straight-line distance of 18½ miles; 22 sections were measured and sampled in detail. Continuous sampling cuts were made through the measured sections in the same way as in sampling an orebody. Approximately 200 samples were examined for foraminifera and a complete list of species contained in each sample was compiled. As far as possible, sections were measured and sampled in continuous sequence directly through the true thickness of the section. In some places, however, it was necessary to compile the section by a series of stepped offsets. As almost all sections measured are cliff exposures, the errors introduced through imperfect observation of dip and calculation of true thickness from outcrop width are few.

As originally planned, publication of the detailed results of this work was not intended. When it became apparent that there were serious errors in the published accounts of the geology of the area, discussions with other workers in the area—notably F. A. Singleton—were clearly desirable. Unfortunately, Singleton died before this discussion could take place. In 1951, when this work was nearly completed, the authors learned that Dr. Owen Singleton, F. Colliver, A. C. Frostick, A. C. Collins and the late W. J. Parr, had a paper in preparation on the area. The authors, therefore, decided to defer publication of their work. After waiting for a year, however, they decided to publish a summary of their results (Raggatt and Crespin, 1952) and they now consider it desirable that a more comprehensive paper should be published. It is to be hoped, however, that the results of the investigation by Owen Singleton and his collaborators will not be lost, particularly in so far as it deals with the shelly fossils, to which only passing reference is made in this paper.

Geographical Names

There are many natural features on the Torquay-Eastern View coast that have not been named. This is not uncommon in Australia, but it is curious that on a coast so near to and so accessible from the cities of Melbourne and Geelong the beaches and headlands of this coast should have gone so long unnamed.

Named natural features are essential not only for general descriptive purposes but for the naming of stratigraphic units. The notes hereunder refer to features that are named for the first time in this paper and to those features concerning which there can be no misunderstanding. The names listed have been submitted to and approved by the Surveyor-General of Victoria. Place names mentioned in the text are shown in Fig. 1.

Addiscot Beach

Name proposed for the beach which extends westerly from the south-west side of Bell's Headland. The name is taken from the name of the property—Addiscot—shown on the military one mile sheet—Anglesea—one mile to the north of the beach.

Bell's Headland

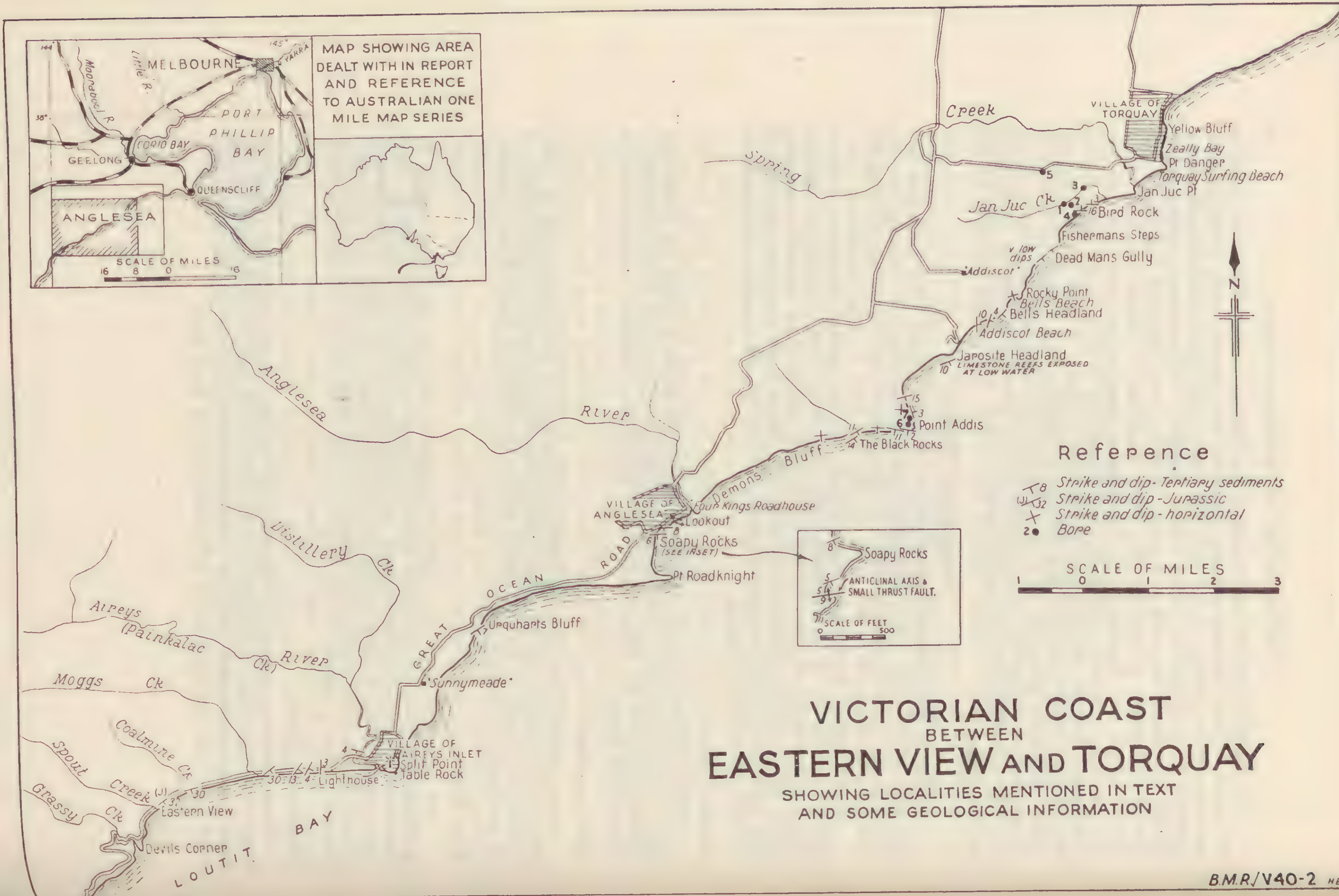
Name proposed for the bold limestone headland at the western end of Bell's Beach. The name is derived from that of the original holder—William Bell—of Portion 19, Parish of Jan Juc, which adjoins the headland. Bell's Beach is shown on the Anglesea military sheet.

Bird Rock

This name has been used (but has appeared only on geological maps) by geologists for many years for the small rock stack about one mile westerly from the mouth of Spring Creek (shown on Lands Department and military maps). The stack is at the western end of the beach (unnamed) at which Jan Juc Creek enters the sea. The steep cliffs adjacent to the stack are known as Bird Rock Bluff (Singleton, 1941).

Fisherman's Steps

Well known to geologists, fishermen and holiday makers, but not named on maps. The steps were originally cut out of the rocks that form the cliffs at this point (Tate and Dennant, 1895, p. 118) but were replaced by wooden steps many years ago. The steps are half a mile south-west of Bird Rock.


MAP SHOWING AREA DEALT WITH IN REPORT AND REFERENCE TO AUSTRALIAN ONE MILE MAP SERIES
MELBOURNE
YARRA
PORT PHILLIP BAY
CORIO BAY
GEELONG
QUEENSCLIFF
ANGLESEA
Moorabool R.
Little R.
SCALE OF MILES
Creek
Spring
VILLAGE OF TORQUAY
Yellow Bluff
Zeally Bay
Pt Danger
Torquay Surfing Beach
Jan Juc Pt
Jan Juc Ck
Bird Rock
Fishermans Steps
v low dips
Dead Mans Gully
'Addiscot'
Rocky Point
Bells Beach
Bells Headland
Addiscot Beach
Jarosite Headland
LIMESTONE REEFS EXPOSED AT LOW WATER
Point Addis
The Black Rocks
Demons Bluff
Anglesea River
VILLAGE OF ANGLESEA
Four Kings Roadhouse
Lookout
Soapy Rocks (SEE INSET)
Pt Roadknight
Soapy Rocks
ANTICLINAL AXIS & SMALL THRUST FAULT.
SCALE OF FEET
Distillery Ck
GREAT OCEAN ROAD
Urquharts Bluff
'Sunnymeade'
Aireys (Painkalac Ck) River
Moggs Ck
Coalmine Ck
Spout Creek
Grassy Ck
VILLAGE OF AIREYS INLET
Split Point
Table Rock
Lighthouse
Eastern View
Devils Corner
LOUTIT BAY
Reference
Strike and dip - Tertiary sediments
Strike and dip - Jurassic
Strike and dip - horizontal
Bore
SCALE OF MILES
N
VICTORIAN COAST BETWEEN EASTERN VIEW AND TORQUAY
SHOWING LOCALITIES MENTIONED IN TEXT AND SOME GEOLOGICAL INFORMATION
B.M.R./V40-2

Jarosite Headland

Name proposed for the headland between Point Addis and Bell's Headland, one mile north-east of Point Addis. It is named after the mineral jarosite which occurs in the cliffs and was once collected and calcined for the production of a red pigment.

Rocky Point

From the earliest times this name has been used for the headland at the eastern end of Bell's Beach, three miles south-west of the village of Torquay (e.g. Tate and Dennant, 1893). The military one mile map (Anglesea) issued in 1921 shows Rocky Point as the headland on the southern side of the mouth of Spring Creek. This point, however, is named Jan Juc or Jan Juk on old plans in the Victorian Department of Lands. The Surveyor-General of Victoria agrees that the oldest use of the name Rocky Point should stand.

The Black Rocks

Name of first point west of Point Addis shown on the Anglesea military sheet as Black Rock. "Black Rock" is a common name around Port Phillip and adjacent areas. Retention of the definite article and the plural will help to distinguish this point from others similarly named. The local people refer to the locality as *The* Black Rocks.

Yellow Bluff

Shown on Singleton's map (1941, Fig. 7) at the northern end of Zeally Bay.

Zeally Bay

Shown on Singleton's map (1941, Fig. 7) as the bay on the northern side of Point Danger. The Zeally family were the original settlers at Torquay. It was they perhaps who named the place Puebla. "Puebla" has been superseded by "Torquay" as the name of the village, but it has been retained for the name of the parish. Point Danger is shown on old Admiralty charts as Zealy Point (spelt with one "l").

Previous Investigations and Conclusions

Since 1863, when Daintree wrote, "On the coast from Jan Juc Creek to Point Addis these . . . beds are seen in splendid cliff sections", a great deal of attention has been paid to this locality.

Daintree (1863) first referred to the sections between Bird Rock and Jan Juc Creek as consisting of two major lithological units but in the marginal note to the Victorian Geological Survey Quarter Sheet 28.S.E. and in the version of the report published in 1898 he recognized three units:

*Upper	80 ft.	Sandy limestone.
*Middle	110 ft.	Brown blue and yellow sandy clay; gypsum abundant in lower 30 ft.
	1 ft.	Hard crystalline sandstone.
	23 ft.	Sandstone and marl with pyrite.
*Lower	1 ft.	Very hard band of crystalline sandstone.
	45 ft.	Sandstone.

Daintree also referred to the "cliffs of sands black with carbonaceous matter" but did not discuss their relationship to the other sediments.

*Not used by Daintree and added here merely to facilitate discussion.

Tate and Dennant (1893, 1895) rejected Daintree's threefold subdivision because they thought the upper limestone was a facies of Daintree's middle beds. Hall and Pritchard (1896) agreed with Tate and Dennant. However, there is no doubt Daintree's subdivision is right in principle, though wrong in detail (see full discussion, pp. 100-101).

Some remarks made by Tate and Dennant in their 1895 paper are relevant to this investigation. They point out (pp. 120-121) that "fallen blocks from the upper levels strew the beach and hitherto collectors have mixed indiscriminately the fossils yielded by them with those gathered *in situ*, the theory being that the fauna was practically indivisible. . . . we offer the suggestion that . . . above the echinoderm-rock (Jan Juc formation of this paper, H.G.R. and I.C.) a minor zone of the Eocene may possibly be demonstrated . . . at any rate the matter is worthy of further research."

In 1902, Hall and Pritchard set out certain principles which they considered should determine the naming of the subdivisions of the Victorian Tertiary:

"As a great amount of work for many years to come will be concerned with the local correlation of our beds, and the elaboration of our sub-divisions, it seems to us advisable to employ local names for the main sub-divisions of our strata. This plan is of world-wide use, and by its adoption we should be making no retrograde step, but would be clearing the way for a detailed consideration of two problems, namely the correlation of our strata between themselves and the correlation with strata elsewhere. If the main types have these names applied to them there will no longer be any need to say whose views one is following, as we need to now, when speaking of certain beds as Eocene or Miocene. The important question as to the relative position of the different formations can be put on one side and need not be forced into consideration in every line of a paper dealing with some small local set of strata.

"Recognizing then the advisability of such a change, it remains to consider what are the principles which should actuate us in our choice. These seem to be few and simple. Firstly, any series of strata with a fauna differing appreciably in its constituents from others should receive a distinctive name. Secondly, the name should be taken from a locality where there is no chance of confusion between the contents of beds of distinct ages. Thirdly, we should not use the names which are used in other parts of the world as names of formations. In the fourth place, it should be understood that the names given are given to a particular set of strata and are irrespective of the correctness or otherwise of the subsequent correlation of other beds with them."

On this basis Hall and Pritchard defined the Balcombian and the Jan Jucian in the following terms:

Balcombian: "The clays and limestones of Balcombe's Bay contain another distinct fauna. The beds are sometimes spoken of as Mornington, but the locality we give is more exact. The Lower Beds at Muddy Creek and the Orphanage Hill beds at Fyansford, near Geelong, are approximately equivalent to the Balcombe's Bay beds, but the exact separation of the two sets of beds at Muddy Creek is not yet sufficiently clear, and a name from that locality would lead to confusion. The beds are called Eocene by Messrs. Tate and Dennant and ourselves. Sir F. McCoy considered them Oligocene."

*Jan Jucian**: "The section near Spring Creek, on the coast of Bass Strait, south of Geelong, is in the main in the Parish of Jan Juc, and its fauna differs

*Later the spelling Janjukian was used.

greatly from that of Balcombe's Bay. The confusion about the age of these beds has been referred to above. The township near Spring Creek is called Torquay, but the use of this name in England renders another advisable. The older name for Torquay was Puebla, but the employment of this name, again, would lead to confusion with certain American strata. The name Jan Juc remains, and is referred to by McCoy as the locality whence several of his fossils came."

The section at Balcombe's Bay is not dealt with in this paper, but as Hall and Pritchard define it, the Janjukian can scarcely be discussed without reference to the Balcombian.

Having defined their units, Hall and Pritchard add the following comment:

"We should like once more to emphasize the point that the names we give are given in the first place to the beds displayed at the localities from which the names are derived, and we are thus able to fix a top and a bottom to each formation. There can be no doubt, except in our opinion in the case of Aldingan and Jan Jucian, of the distinctness of the faunas they typify."

The status, in terms of modern concepts, of units thus defined is somewhat dubious. The first criteria suggested—difference of faunas—is unreliable in a region where facies changes are common and difficult to trace because good exposures are widely separated. It is unfortunately not true that in the sections nominated as types for the Janjukian and the Balcombian "a top and a bottom" can be fixed.

It is not surprising that confusion resulted, that different opinions have been expressed as to the relative stratigraphic position of the Balcombian and Janjukian, and that the term "Barwonian" (Hall and Pritchard, 1904, pp. 297-8) was suggested to include beds with faunas not clearly referable to either Balcombian or Janjukian.

In 1910 Hall gave a good generalized description of the sections exposed between Torquay and Eastern View. He made reference to several of the features described in this paper and his contributions will be noted in their proper place. At this point, however, attention is directed to the fact that although in this paper Hall, by use of the following phrase, clearly recognized the relationship of the limestone of Rocky Point to the black sandy clays—"the fossiliferous yellow limestone of Rocky Point . . . on rounding a small point [Bell's Headland.—H.G.R.] is seen to overlie purple and black sandy clays . . .",—he not only considered the fossiliferous black beds at Anglesea as a marine phase of the coal measures at Eastern View but apparently he regarded the beds in the lower part of the Bird Rock section as a facies of the "purple and black sandy clays". He wrote: "as we go north-east along the coast [from near Airey's Inlet.—H.G.R.] the influence of marine conditions is more strongly felt and near Anglesea marine fossils . . . are sparingly found. Still farther on the character of the beds beneath the yellow limestone changes; gravels and grits disappear and at Rocky Point marine fossils of all kinds are common, the beds becoming richer as we approach Bird Rock."

The first statement quoted above seems to have been overlooked by later investigators. It refers to the only known section showing a passage from the black sandy clays to the overlying marls and limestones and examination of it would have saved much of the fruitless discussion which has taken place on the relationship of the "Janjukian" to the "Anglesean".

In the absence of a precise definition of "Janjukian" either as a rock or time-rock unit, the term was extended to include beds proved by boring below those exposed in the type locality. A bore which was put down to a depth of 70 ft.

between Bird Rock and Fisherman's Steps (i.e. immediately below the lowest beds of the type section) was reported upon by Chapman (1922a) in the following terms:

"The foregoing results of an examination of the detailed structure and contents of the Torquay boring prove that down to 70 ft. the strata are still in the Janjukian series.

"The fact that green sands and marls with a Janjukian fauna prevail throughout, points to a downward extension of the lower beds of the Bird Rock Cliffs, at least 70 ft. below the level of the boring at the surface.

"Judging by the sections in the Mallee bores and in South Australia, there should come below these green sandy marls a series of estuarine and brackish water beds, as are indeed found at Anglesea and elsewhere along the Otway coast.

"Such restricted fossils as *Mopsea hamiltonensis*, *Venus* (*Chione*) *halli*, and *Volvula inflatior*, point to the Janjukian age of these lower strata with certitude; whilst a numerous fauna, which, although not restricted, is more typical of Jan Jucian beds, is well represented in this series. Amongst the latter are: *Carpenteria proteiformis*, var. *plecte*, *Turritella gemmulata*, *Marginella kitsoni* and *Mangilia sandleroides*." (The log of this bore is given on p. 196.)

In 1925 Pritchard himself, writing about the Janjukian, stated that "the total thickness as measured on the cliff faces from the south of Spring Creek to the centre of the Bird Rock Dome is about 183 feet, but the actual thickness of this marine series is rather more than 1,000 ft."

Chapman and Singleton (1925) stated that greensands and marls similar to those proved by the 70 ft. bore reported upon by Chapman (1922a) had been proved by later boring to a depth of 170 ft. below sea level. (The beds thus referred to, however, are stratigraphically higher than those penetrated by the 70 ft. bore; see discussion, pp. 114, 121, and Fig. 4.) In this paper (p. 997) they wrote:

"In Victoria this series (Janjukian) is represented by the lignitiferous beds with *Cyclammina* found in depth in the Torquay bores and outcropping farther along the coast in the high cliffs between Point Addis and Anglesea."

This statement cannot be reconciled with Chapman's earlier (1922a) remarks quoted above unless in the intervening time it is assumed that he came to accept the views expressed by Pritchard in 1925.

In 1941* Singleton re-defined the Janjukian as a time unit in the following terms:

"The Janjukian may be defined as the interval of time represented by the deposition of the marine beds outcropping in the coastal sections, about three miles in length, between Rocky Point and the mouth of Spring Creek, in the Parish of Jan Juc, and proved in borings to a depth of 170 ft. below sea level, as well as those represented therein by non-deposition or erosion."

This definition, like the earlier one of Hall and Pritchard, is open to the objection that it refers to an interval of time represented by a partial sequence. The base of the sections is not related to any formational contact and no criterion is suggested by which it may be recognized; the upper limit is a modern erosion surface. As

*So far as Tertiary stratigraphy is concerned, and especially that of the coastal sections described in this paper, Singleton gave only the barest outline of his conclusions in his 1941 paper. Singleton had a unique knowledge of the Australian Tertiary shelly faunas, and it is a matter for great regret that he died before much of his work was ready for publication. However, it is his published work that is quoted, and it is unavoidable that errors therein should be indicated.

mentioned above and discussed later (p. 121) the beds "proved in borings to a depth of 170 ft." are above those proved by the 70 ft. bore described by Chapman (1922a).

Singleton (1941) put forward the name "Anglesean" in the same dual sense as Hall and Pritchard proposed their names. Thus he defined it (p. 24) as "black sandstone and sandy clays . . ." at Anglesea and (p. 25) as "the interval of time represented by the deposition of the dark-coloured sands with *Cyclammina* of the cliff sections between Anglesea and Point Addis, ..." At the time he proposed this name Singleton could have given only cursory consideration to the Anglesea section. He stated that "the upward limit of the Anglesean is given by the overlying unfossiliferous white sands", but the beds to which he refers as unfossiliferous differ little except in colour from those of the type "Anglesean". He discussed the relationship between the "Anglesean" and "Janjukian" and postulated the existence of a "Stage" between the two (p. 65). Owen Singleton (F. A. Singleton's son) states, in a note written to E. S. Hills, that his father had found evidence proving that the "Junjukian" rested conformably on the "Anglesean". As stated on page 81 Hall had directed attention to the section showing this relationship, in 1910.

Description of Sections

In this part of the paper a description of each section that was measured and sampled is given, together with a list of the foraminifera contained in the samples. Brief notes are included giving the geographical and approximate stratigraphical relationship of the sections to each other.

In the next part of the paper reference is made to the sections described in this part and they are placed in their correct stratigraphic position. It is hoped that this arrangement of the subject matter will facilitate recognition of localities and beds from which fossil collections have been made.

The sections are described in this sequence: Anglesea; Anglesea to Rocky Point; Bird Rock; Bird Rock to near Rocky Point; Bird Rock to Torquay; westward from Anglesea to Eastern View.

Anglesea River to Demon's Bluff

Singleton's type section for the "Anglesean" (see his Plate 1, Fig. 1, 1941) is about midway between the mouth of the Anglesea River and the Demon's Bluff Trig. Station. Examination of the section shows that it consists of two main lithological types. The lower part of the cliffs consists of clayey carbonaceous siltstone which are dark brownish grey (SYR3/1)* on exposed surfaces but a brownish black (SYR2/1) when freshly broken. The upper beds are fine quartz-clay greywacke. At and near their base they are pale red purple in colour; the colour intensity of the beds decreases upwards (from SRP6/2 to SRP5/2). The highest are yellowish. The rocks here designated siltstone and greywacke are not markedly different in composition or grain size, and it is possible that a more detailed examination might not support the use of the lithological names that have been adopted. (Glover, 1954; Dallwitz, 1954.)

However, as the rocks are different in appearance it is useful to differentiate between them. The section described hereunder was measured and sampled at the type locality. The sequence is in descending order.

*Refers to colour chart prepared and issued by the Rock-Colour Chart Committee, U.S. Geological Survey.

SECTION 1

Sample No.	Thickness (ft.)	Description
E.17	4	Fine quartz-clay greywacke; some organic matter in lowest beds but less and less upwards; *Cyclammina* common; particularly abundant in lower 10 ft. Bedding planes poorly preserved, but cross-bedding marked by ochreous concretionary nodules.
E.16	7	
E.15	6	
E.14	5	
E.13	5	
E.12	5	
E.11	5	
E.10	4	Pale red-purple fine quartz-clay greywacke; *Cyclammina* especially abundant in lower 10 ft.; generally otherwise like lower siltstones including abundance of worm burrows and "algal" remains.
E.9	5	
E.8	5	
E.7	5	
E.1	11	Clayey carbonaceous siltstone with abundant white worm burrow fillings and "algal" remains. *Cyclammina* common at top, but rare in lower part. Rock structureless in hand specimen, but bedding planes identifiable in cliff. Upper surface eroded in places.
E.2	7	
E.3	7	
E.4	7	
E.5	11·5	
E.6	5	
E.1-E.17	104·5	

The beds E.1-E.6, 48·5 ft. thick, correspond to Singleton's "41 feet of black sandstone"; the beds E.7-E.17, 56 ft. thick, correspond to his "47 feet of unfossiliferous white sands". Part of this section is illustrated in Pl. IV, Fig. 3.

In the cliffs at Demon's Bluff, 2 ft. above the contact of the siltstone and the greywacke, lenses up to 2 ft. thick occur which, in colour and lithology, are indistinguishable from the siltstone.

The siltstone, wherever seen, has the same lithology and is marked by closely spaced nearly vertical jointing. On the walls of the joints it is not uncommon to find radial markings. The easiest way to give a mental picture of the markings is to liken them to a lady's fan (but circular) open almost to its full extent. The commonest diameters noted are nine inches to two feet. It is considered most probable that these markings were formed as part of the process of development of tension joints (Woodworth, 1897). The tension joint markings apparently have not been noted previously, but Hall (1910) remarked—"the chief peculiarity of the black series is its jointing . . . great sheets flake off the vertical cliffs and fall or hang in threatening positions nearly 100 feet above the beach".

The distribution of foraminifera in the samples from Section 1 is shown in Table I. The samples are arranged in ascending sequence.

Anglesea River to Point Roadknight

A section with many features in common with that described above is exposed west of the Anglesea River. Much of the section can be viewed from the lookout on the Great Ocean Road at the top of the hill south-west of Four Kings Roadhouse. The photograph, Pl. IV, Fig. 2, is taken from this viewpoint.

The disconformity noted on the eastern side of the river between the siltstone and the greywacke is much more marked on the western side. The section hereunder illustrates this.

The siltstones closely resemble the beds E.1-E.6 and the beds 30 ft. thick below the "marked bedding plane" shown on the section are very much like E.7-E.10.

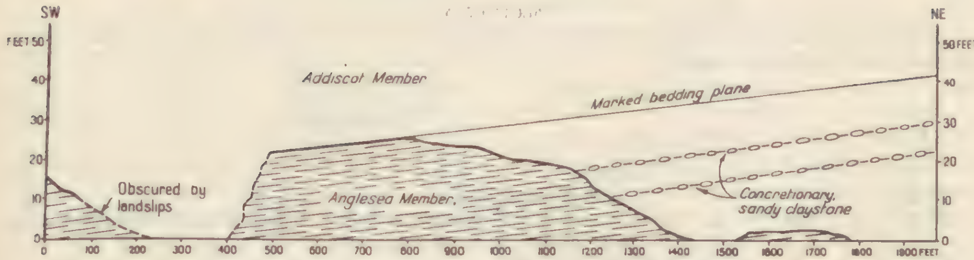


FIG. 2.—Section at Anglesea showing disconformable contact of Addiscot and Anglesea Members.

This 30 ft. interval, however, includes two thin concretionary sandy claystone beds, with abundant *Cyclammina*, which end sharply against the erosion surface as indicated in the above Fig. 2. Because of this general similarity between the sections and because *Cyclammina* is readily identifiable in hand specimens, sampling at this point was restricted to a limited interval, below and above the disconformity, with the object of seeing whether there was a faunal change related to the erosion surface. The partial section described below was measured at the locality of Fig. 2.

SECTION 2

Sample No.	Thickness (ft.)	Description
—	0 - 0·5	Off-white, concretionary, sandy claystone.
W.3 W.2	5·5 10·0	Pale red-purple greywacke (cf. E.7-E.10).
		Erosion surface.
W.1	3·0	Brownish black clayey siltstone (cf. E.1-E.6).
—	—	Beach.

The distribution of foraminifera in the samples from Section 2 is shown in Table II. The samples are arranged in ascending sequence.

Commencing at the top of the siltstone a continuous section was measured from a point about 200 ft. west of a point vertically below the lookout, through Soapy Rocks to the boat harbour inside Point Roadknight. Details of this section are given in Section 3.

The following details will enable the several units in the section to be recognized in the field (see Pl. IV, Fig. 2):

W.4 to W.12—Continuous cliff exposure from starting point of section southerly to end of beach (at high tide) at Soapy Rocks. W.12 is easily identified by its yellowish-green efflorescence.

W.98 and W.99—Soapy Rocks. (Breccia, agglomerate and ripple-marked tuffaceous sandstone are easily identified.)

W.100—Small cove on south side of Soapy Rocks readily identified by small anticline and overthrust fault.

W.101 and W.106—W.101 forms small headland at high tide. South of this the boat harbour beach extends without interruption to Point Roadknight. W.106 and overlying white clay are clearly exposed on top of W.101.

SECTION 3

W.105—The clays and sandstone form cliffs at the back of the northern end of the boat harbour beach.

Sample No.	Thickness ft.	in.	Description
—	–	–	Surface.
W.105	–	–	Top 6 ft. of W.102.
W.102	30+	0	Red, brown and yellow claystone, irregularly interbedded with fine brown sandstone.
W.—	0	2-8	Light grey clay.
W.106	0	4/18	Volcanic conglomerate with pebbles up to 2½ in. diameter. Passes into brown sand (mixture of quartz and coprolites) with pebbles of basalt up to 2½ in. diameter.
W.101	15	0	Fine, thinly cross-bedded sandstone; yellow at outcrop.
W.100	6	0	Finely laminated silty sandstone grading downwards into sandy mudstone; 2 in. carbonaceous layers. In places lower 4 in. shows "worm-track" lithology.
W.100a	–	–	Lower 6 in. of W.100.
W.99	4/6	0	Clayey volcanic agglomerate including 9 in. laminated tuffaceous sandstone at top; upper surface ripple-marked.
W.98	6/12	0	Shale-volcanic breccia.*
W.12	1	6	Shale.
	0	9	Shale with jarosite efflorescence.
	0	9	Shale.
	0	2	Brown coal.
W.11	9	0	Grey fine greywacke. Sharp change in lithology above this bed.
W.10	12	0	Grey fine greywacke.
W.9	12		2 ft. pale red-purple clayey greywacke with worm burrows. 4 ft. pale red-purple greywacke with thin shale partings.—Layer of quartz pebbles up to ½ in. diam. 6 ft. Same as top 2 ft.
W.8	11		Pale red-purple greywacke. *Cyclammina* abundant in groups.
W.7	10		Pale red-purple greywacke with worm burrows; *Cyclammina* common in groups.
W.6	3		Pale red-purple greywacke.
W.5	11		Pale red-purple greywacke with some thin brownish-black bands in lower half; top weathered deep red; worm burrows.
W.4	5		Cf. W.5; 6 in. dark band at top.
Erosion surface			
–	–		Brownish-black *Cyclammina*-bearing clayey siltstone.

*Identified also by Hall (1910) who records thickness as 12 ft.

This section is made up of three, perhaps four, units in descending sequence:

Sample No.	Thickness (ft.)	Description
W.102	30	Clays and sandstone poorly bedded and probably in part tuffaceous. Laid down in fresh water.
W.12-W.106	39	Well bedded fluviatile sediments and some volcanic material.
W.4-W.11	73	Greywacke containing much organic matter probably deposited under estuarine conditions after slight uplift and erosion of unit below.
—	—	Similar to unit above but finer grained and containing more organic matter.

Cyclammina is so abundant and easily identified in the two lower units as to be a lithological characteristic.

The ferruginous coarse sandstone to conglomerate (white quartz pebbles commonly $\frac{1}{4}$ to 1 in.; some 3 in. diameter) from which is derived the pile of rocks on the beach at the eastern end of the cliffs below the lookout, is lenticular and does not occur where the foregoing section was measured. Its base is 12 ft. above the base of W.4 and its maximum thickness is 12 ft.

There is no doubt that the siltstone and overlying greywacke, both with *Cyclammina*, on either side of the Anglesea River, are parts of the same formation and that the beds represented by W.12 and W.102 on the west side of the river are stratigraphically higher than any bed exposed on the east side of the river.

The distribution of foraminifera in the samples from Section 3 is shown in Table III. The samples are arranged in ascending sequence.

The higher beds are unfossiliferous.

Demon's Bluff to The Black Rocks

The apparent anticlinal structure between Anglesea River and The Black Rocks has been explained in two ways—by Singleton (1941) as an anticline, and by Hall (1910) as a weathering effect.

Referring to this and other sections, Hall (1910) has suggested that the gradation in colour of these beds from nearly black through dark brown to pale purple is a function of Recent to Sub-Recent weathering, but this is clearly incorrect. As stated earlier in this paper, the contact between the dark- and light-coloured beds in places is marked by a contemporaneous erosion surface and there are small dark-coloured lenses interbedded with the light. The colour differences are, therefore, an original condition of the sediments; it is true, however, that the darkness of the lower beds is accentuated in places by their being continually moist with sea spray.

On the western side of the Anglesea River the beds dip 8° on a bearing of 165° and at The Black Rocks 12° on a bearing of 133°. There is, therefore, a possibility that the beds are part of an anticline plunging south-westerly. The apparent anticlinal structure is accentuated by the fact that the beds are exposed on a curving cliff front which, in plan, is concave facing the direction of dip.

From Demon's Bluff to The Black Rocks the same beds as those described at Anglesea are well exposed and there is an excellent, easily accessible cliff section showing the contact of the carbonaceous siltstone and the greywacke on the western side of The Black Rocks (see Pl. V, Fig. 1). At this locality the two units are conformable. There is a great abundance of *Cyclammina* in the greywacke. The Black Rocks themselves are formed by a pebbly sandstone with ferruginous cement. Its base is 33 ft. above the top of the carbonaceous siltstone and it locally attains a thickness of 40 ft.

The Black Rocks to Point Addis

It is clear that part at least of the uppermost freshwater beds exposed on the west side of the Anglesea River are present between The Black Rocks and Point Addis, but the beds are so disturbed by slumping that the section cannot be measured. Several samples were collected and examined for foraminifera, but none were found.

Point Addis

Point Addis is a prominent headland composed mainly of calcarenite overlain by marls and clays. The more massive beds forming the headland are somewhat irregularly bedded and it is therefore difficult to trace individual beds very far. From immediately north of Point Addis a beautiful curved beach extends for a

mile to Jarosite Headland. The cliffs at the back of this beach are formed of beds closely resembling those at Anglesea.

SECTION 4
(Measured in descending order)

Sample No.	Thickness ft.	in.	Description
PA.11	3	0	Cream to white friable calcarenite.*
E.110-a	7	0	Cream marl.
E.110-b	7	0	Fawn to pale yellow marly siltstone.
E.110-c	7	0	Cream marl.
E.110-d	9	0	Bryozoal sandy marl.
P.A.10	12	0	Grey marly siltstone.
PA.9	1	6	Calcarenite; friable, cream.
	1	6	Calcarenite; tough, cream.
	1	6	Calcarenite; friable, cream.
	4	0	Calcarenite; tough, cream.
PA.14	1	0	Calcarenite } cream to yellow.
	1	6	Siltstone
	0	10	Calcarenite
	3	0	Siltstone
	1	0	Calcarenite
PA.13	2	3	Silty marl } cream to yellow.
	0	6	Calcarenite
	3	0	Silty marl
PA.12	4	0	Calcarenite
	5	6	Silty marl with small lenses of calcarenite; yellow.
	0	2	Limestone conglomerate; pebbles commonly ½ in. to 1 in. and up to 1½ in.
PA.7 and PA.8b	6	6	Calcarenite, cream to yellow (two samples of same bed at points 100 ft. apart; see sketch below).
PA.15	10	6	Calcarenite, cream to yellow.
PA.6	5	0	Brown gritty clay.
PA.16	40	0	Chiefly grey and yellow sandy clay with some brown clayey sandstone. Exposure poor and incomplete.
—	0	3/6	White and grey clay.
E.112d	3	0	Grey clayey sandstone.
PA.1	5	0	Brown and grey clayey sandstone with occasional quartz pebbles up to ½ in. diameter. *Cyclammina* abundant.
PA.2	6	6	Grey sandstone with thin black lenses showing worm burrow lithology; *Cyclammina* abundant.
PA.3	3	0	Like PA.2—blocky jointing.
—	0	2/12	Quartz grit to quartz gravel bed.
PA.4	8	0	Top 1 ft. like PA.3 but downwards lithology increasingly resembles that of upper beds E.7/E.17 of Section 1. Purplish tinge on weathered face.
—	12	0	Same as lower part of PA.4.
PA.5	5	0	As above, with some black lenses and layers of fine white sand. Abundant sand-filled worm burrows.

*As indicated earlier in this paper, the work on which it is based was not undertaken in the first place with publication in mind; consequently insufficient attention was given to the lithology and composition of the sedimentary rocks. Comments on some of these are given by W. B. Dallwitz and J. E. Glover in this journal. These comments indicate that considerable care is necessary in the naming of the sedimentary rocks if they are to be classified correctly and differentiated from each other.

Particular attention is directed to the calcareous rocks in the cliff sections between Point Addis and Torquay, where alternations of beds resistant to erosion with beds that erode easily are common. Over the years a tendency has developed to use the words "hard" and "soft" instead of "tough" and "friable" to distinguish between these beds. The so-called "hard" rocks are in fact generally more calcareous than the "soft" ones; they resist weathering and erosion because of their finer grain size and cementation by calcium carbonate.

The beds PA.9 to PA.11 were measured continuously upwards from the top of the cliff at the extreme point of Point Addis. PA.12 to PA.14 were measured on the western side of the Point, i.e. at the eastern end of the beach between Point Addis and The Black Rocks. PA.7, PA.15 and PA.6 were measured north of the Point and from there round to the slumped outcrops where the outcrops of calcarenite end and the long curved beach begins. The beds in PA.16 were measured at low water in front of the slumped outcrops on the northern side of the Point; the beds from E.112d downwards are in continuous sequence on the north side of the slump. The limestone-conglomerate at the base of PA.12 marks a surface of contemporaneous erosion; it resembles closely the modern wave cut platforms in the limestone. The same surface can be identified at Bell's Headland.

The relationship between the beds represented by samples PA.7, PA.8b, PA.15 and PA.6 is best explained by a sketch (Fig. 3).

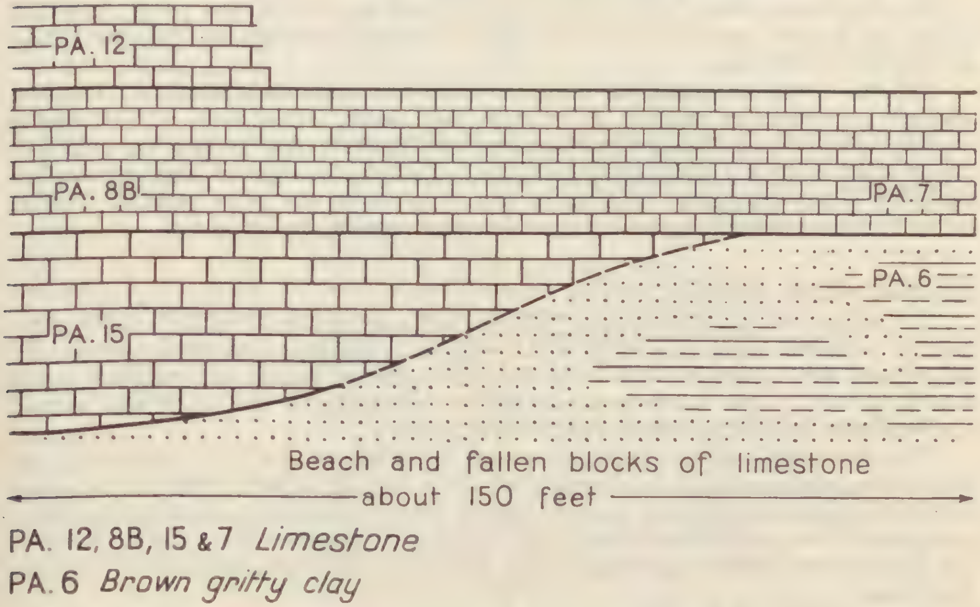


Fig. 3.—Sketch Section N.E. side of Point Addis.

The dark-coloured *Cyclammina*-bearing beds from E.112d downwards correspond to beds of similar lithology at Anglesea and The Black Rocks, but a more precise correlation is difficult to make. There is little doubt that broadly the beds represented by W.12 to W.105 in Section 3 can be correlated with E.112d to PA.6.

In 1923 (D.M., V., 1938, 17-18 and Plate 3) two bores were put down for oil at Point Addis. The bores were 822 and 842 ft. deep respectively and if the cuttings had been kept, or a log prepared at the time by a trained observer, information of considerable value would have been obtained, but only the driller's logs are available and these, despite the great variation in colour and lithology of

the beds drilled, have only limited value for stratigraphical purposes. (See discussion p. 114.)

The distribution of foraminifera in samples from Section 4 is shown in Table IV. The samples are arranged in ascending sequence.

Jarosite Headland

The beds exposed between Point Addis and Jarosite Headland are the same as those which form Demon's Bluff. At Jarosite Headland, on both sides of the former haulage way from the beach to the site of the old jarosite treatment works, nearly vertical cliffs give a good section of the greywacke and siltstone represented in the sections at Anglesea. The peculiar worm burrow lithology is well shown; *Cyclammina* and pyritic concretions are common; marked, closely spaced, vertical jointing is well developed and on some of the joint surfaces the tension joint markings noted at Anglesea are preserved.

The cliff section was measured at its highest point. There are 80 ft. of pale red-purple greywacke and 35 ft. of brownish black siltstone at this point. Adjacent to the old jarosite haulage way a conformable contact between the two units may be examined with ease.

Off-shore from the headland there are three limestone reefs which are exposed and are accessible by wading at extreme low water. These beds dip 10° on a bearing of 145° and clinometer measurements indicate that if this dip is maintained toward the headland the limestones are above the highest beds exposed on the cliffs. Thus the limestone forming the reefs are in the same position relative to the *Cyclammina*-bearing beds as are the limestones at Point Addis.

Bell's Headland–Addiscot Beach

Bell's Headland is a prominent bluff formed predominantly of calcarenite overlain by siltstone and clay. On its south-west side, siltstone and marl are exposed underlying the calcarenite and beds still lower in the section are exposed at the mouth of, and on the south-west side of, a small gully on the south-west side of the headland (northern end of Addiscot Beach).

The dip of the beds on the south face of the headland is 4° on a bearing of 95° and on the south-west side of the gully 10° on a bearing of 80°. With the exception of a small gap where the gully meets Addiscot Beach, there are continuous exposures downwards through siltstone and clay, calcarenite, siltstone with shelly fossils to the *Cyclammina*-bearing greywacke and siltstone which form the cliffs at Jarosite Headland.

Beds represented by different groups of samples were measured and sampled in the places listed hereunder:

B.70 - B.73—Top of headland vertically above where south-west side of cliffs meets the beach.

B.74 - B.75—Immediately below B.73. The ledge formed by the weathering out of the 2 ft. bed at the top of B.75 may be easily identified and traced round the face of the headland. This ledge is formed by weathering of the contemporaneous wave-cut surface which is referred to in the description of the section at Point Addis. At Bell's Headland there are no pebbles on this surface but it is deeply honeycombed and is littered with macerated shells.

B.91 - B.101—Beginning at lowest outcrop on south-west side of headland in ascending sequence by a series of steps normal to the dip as successively higher

SECTION 5

(Measured in descending order.)

Sample No.	Thickness ft.	in.	Description
B.70	5	0	Yellow clayey siltstone.
B.71	8	0	Brown and yellow siltstone.
B.72	5	0	Brown and yellow siltstone; including 3 in. nodular layer at base.
B.73	8	0	Grey and yellow siltstone; abundant limestone nodules, weathered white.
B.74	10	0	Calcarenite; shelly fossils.
B.75	2	0	Shelly friable calcarenite; weathered out forming prominent feature (Diastem).
	8	0	Calcarenite; some shelly and friable. Top forms ledge to feature above.
—	10	0	Calcarenite—chiefly tough; some shelly and friable.
B.91	6	0	Calcarenite—chiefly tough; some shelly and friable.
B.92	3	3	Calcarenite; shelly and friable.
	0	10	Calcarenite; tough.
	3	4	Calcarenite; shelly and friable.
B.93 (5ft.)	9	3	Calcarenite; some tough, some friable.
B.94 (8ft.)	3	10	Calcarenite; tough. Crops out on rock platform and probably is lower bed of reefs opposite Jarosite Headland.
B.95	6	6	Calcarenite; cream, chiefly shelly and friable; some tough.
B.96	5	0	Siltstone; thin brown and grey alternating layers.
B.97	1	9	Siltstone; upper 9 in. grey, lower 1 ft. brown.
B.98	2	0	Calcarenite; tough.
B.99	1	6	Marl with white calcareous nodules.
B.100	5	6	Grey clayey siltstone; abundant shelly fossils in lower foot.
B.101	0	9	Finely laminated yellow clayey siltstone.
	2	0	Calcilutite; forms prominent outcrop across beach.
	0	6	Marly siltstone.
—	18	0	Estimated—no outcrop.
B.107 (B.102)	0	3/6	Quartzose calcilutite.
	6	0	Grey siltstone; abundant gastropods; much gypsum. (B.102—upper 2 ft.)
B.104	—	—	B.108 plus lower 4 ft. of B.107.
B.108	2	0	Mottled brown and yellow siltstone; cross-bedded.
B.103	1/2	0	Calcilutite; forms prominent outcrop across beach.
B.109	1	0	Grey clayey siltstone; abundant gastropods; much gypsum.
B.110	6	0	2 ft. 6 in. mottled brown and yellow sandstone. 6 in. to 2 ft. calcilutite; lenticular. 2 ft. 6 in. mottled brown and yellow sandstone.
B.111	6	0	Mottled brown and yellow sandstone.
B.112	7	0	Brown and white sandstone.
B.113 (top 6 ft.)	45	0	Pale red-purple, mottled white, greywacke with worm burrow lithology and *Cyclammina*.
—	0	6	Layer of well-rounded quartz pebbles up to ½ in. diameter.
—	–	–	Erosion surface.
B.106 (top 15 ft.)	37+	0	Brownish black siltstone with worm burrow lithology; abundant "algal" remains and *Cyclammina*.

beds are accessible from north-west to south-east; thence along and up the seaward face of the headland.

Below B.101—Beds at mouth of gully on south-west side of headland traced upwards and south-easterly to top of cliff; continuous section measured and sampled therefrom to beach level.

The section may be summarized thus:

ft.	in.	Description
26+	0	Siltstone and clay containing calcareous nodules. B.70 - B.73.
63	0	Calcarenite—chiefly tough; some shelly and friable. B.74, B.75, B.91 B.95.
49	0	Siltstone and clayey marl, containing abundant small gastropods and some non-fossiliferous calcilutite. B.96 - B.109 including zone of no outcrop.
19	0	Loosely cemented brown and white mottled siltstone and sandstone. B.110-B.112.
45	0	Pale red-purple mottled white, greywacke with *Cyclammina*. B.113.
–	–	Disconformity marked by erosion surface and layer of quartz pebbles.
37+	0	Brownish black siltstone with *Cyclammina*. B.106.

The distribution of foraminifera in the samples from Section 5 are shown in Table V. The samples are arranged in ascending sequence.

At Bell's Headland and Addiscot Beach the general sequence—calcareous rocks overlying *Cyclammina*-bearing sediments—is similar to that exposed at Point Addis and Jarosite Headland. At Point Addis the beds between the two main formations are poorly exposed and at Jarosite Headland they have been eroded away. At Bell's Headland, however, an almost unbroken sequence is exposed from the *Cyclammina* siltstone to the limestone. *It is, in fact, the only section known in the district showing this part of the sequence.* It is interesting to note that at this locality all the beds exposed appear to be marine; whereas at Anglesea there are freshwater deposits above the *Cyclammina* siltstone.

Rocky Point

Bell's Beach lies between Bell's Headland and Rocky Point. There is a small outcrop (70 ft. long and 20 ft. high) of limestone at the back of the south-west end of the beach, but from that outcrop to Rocky Point—a distance of about 500 ft.—there are no exposures.

The section, described hereunder in descending sequence, is exposed at Rocky Point (see Plate V, Fig. 2):

SECTION 6

Sample No.	Thickness ft.	in.	Description
RP.9	5	0	Yellowish brown sand.
RP.8	2	0	Yellow siltstone with discontinuous 9 in. limestone bed at top.
—	5	0	No outcrop; covered by talus and soil.
RP.7	5	0	Yellow siltstone with small calcareous concretions.
RP.6	5	0	
RP.5	5	0	
—	12	0	No outcrop; covered by talus and soil.
RP.4	3	0	Marl; bottom half tough and shelly; upper half friable and non-shelly.
RP.3	5	10	2 ft. 1 in. Glauconitic foraminiferal calcarenite; tough. 1 ft. 3 in. Glauconitic foraminiferal calcarenite; friable. 2 ft. 6 in. Glauconitic foraminiferal calcarenite; tough. (The projecting bed which gives the headland its characteristic appearance.)
RP.2	3	6	Calcarenite; friable; shelly in part.
RP.1	0	7	Calcarenite; tough.
	9	2	Calcarenite; shelly, friable.
	2	0	Calcarenite; tough. Bed forming rock platform.
	1	0	Calcarenite; tough. Lowest exposure at low water.

Although the exposures at Rocky Point and Bell's Headland are only ¼-mile apart precise correlation between them requires care. The small isolated exposure at the back of the south-west end of Bell's Beach has an apparent dip 45° at 2°. The section includes a prominent bed about 18 in. thick. Sighting up the dip along this bed towards Bell's Headland suggests that it is the same as a bed exposed on the Headland in a stratigraphical position about 4 ft. below the top of B.74; sighting down the dip suggests that it is the same as the prominent ledge-forming bed in RP.3.

The distribution of foraminifera in samples from Section 6 is shown in Table VI. The samples are arranged in ascending sequence.

From Rocky Point to Torquay there is an unbroken line of cliffs. The section exposed on these cliffs is described in reverse geographical order to that used so far in this paper, for two reasons:

(i) The horizon markers used for correlation die out from east to west and and it is more convenient to describe them in that order than in the reverse one.

(ii) The exposures at Bird Rock and Fisherman's Steps are virtually the type section for the "Janjukian" so that it seems preferable to describe the section in this order—

(a) Bird Rock, thence westerly through Fisherman's Steps to Rocky Point;

(b) Bird Rock to Torquay.

Bird Rock and adjacent Bluff

There are many references in the literature to the section at Bird Rock and the adjacent bluff, the best known of the "Janjukian" sections in the Torquay-Anglesea area, but all published descriptions of it except Daintree's (1863) are in general terms. Daintree's description (see p. 79) is accurate but not sufficiently detailed for the present purpose. Section 7, described below, was measured in descending order at the point nearest to Bird Rock and the adjacent cliffs on the eastern side thereof.

The different units in this section may be recognized by reference to the following notes and to Plate VI, Fig. 1.

Broadly, as pointed out by many previous workers, the section consists of two parts—the upper friable, fine-grained and relatively less fossiliferous beds, and the lower, coarser-grained and richly fossiliferous beds. The top of BR.5 (Marker "F")—not, as has been stated (Hall and Pritchard, 1896) the hard bed (Marker "E") that forms the top of the Bird Rock stack—is the surface which naturally divides the sequence into two parts (see Plate VI, Fig. 1). The top of this bed (BR.5) is a well-marked dip surface on the eastern side of the Bird Rock Bluff where the beach ends against the rocks that form the point. Resting on it will be seen the slumped outcrops of BR.4. With this as a reference point there will be no difficulty in recognizing the higher units.

The section comprised by samples BR.5 and those below BR.5 form the lower part (an almost vertical cliff face) of the Bird Rock Point and the beds from "E" down to the base of BR.17 form Bird Rock itself. The 6 in. relatively tough bed at the top of BR.18 goes under Bird Rock on its eastern side. Bed "D" (the *Glycymeris* bed) crops out on the rock platform 50 ft. west of Bird Rock. If any difficulty is experienced in identifying it here it can be recognized very easily on

SECTION 7

Sample No.	Marker Bed*	Thickness ft.	in.	Description
—	—	5	0	Clay and soil.
BR.13	—	15	0	Mottled yellow and grey laminated siltstone.
BR.12	—	0	2	(a) (a) Nodular limestone (calcilutite)
		3	1	(b) Nodules white on exposed
		0	7	(a) surface.
		3	6	(b) (b) Marly siltstone
BR.11	—	1	1	Average of 10 in. - 1 ft. 4 in.; (a) similar to BR.12
		1	7	(b)
		0	5	(a)
		0	10	(b)
		0	3	(a)
		0	5	(b)
		0	7	(a)
		2	0	(b)
BR.10	—	0	9	Limestone similar to higher beds.
		2	0	Greenish grey marly limestone.
BR.9	—	5	3	Yellow and grey siltstone.
—	—	8	9	Yellow and grey clayey siltstone; calcareous concretions (calcilutite) at L, M and N. Beds not sampled owing to difficulty in obtaining clean outcrop. (See BR.19 to BR.25 in Section 8.)
—	N	–	–	
—	—	15	0	
—	M	–	–	
—	—	12	0	
—	L	–	–	
BR.8	—	5	2	Grey clayey siltstone.
BR.7	K	0	8	Grey quartzose marl; two pale yellow concretionary limestone (calcilutite) beds at top "K" and calcareous concretions "J"; gastropods common.
		0	8-12	
		0	8	
		2	6	
	J	0	9	
		9	0	
BR.6	H	2	0	Calcilutite; tough. Forms prominent outcrop marked by weathering out of beds below.
BR.1	—	6	2	Grey to yellow clayey siltstone.
BR.2	—	8	0	
BR.3	—	3	3	Grey clayey siltstone; abundant gastropods. Mud balls commonly about ½ in. diameter.
BR.4	G	13	0	Grey silty argillaceous calcarenite with a few calcareous concretions 3 ft. long at 1 ft. from top. Poorly exposed due to slumping. (BR.4 = bottom 4 ft.)
BR.5	F	5	0	Grey friable calcarenite; abundant glauconite and shelly fossils particularly at top; lenticular, tough band "F" at top.
BR.14	E	1	0	Grey friable calcarenite.
		1	0	Top of Bird Rock stack.
		4	0	Grey friable calcarenite.
		1	0	Brown calcarenite; harder than bed below and bed above.
BR.17		3	6	Grey friable calcarenite.
		6	0	Grey friable calcarenite; top marked by ledge on side of Bird Rock.
BR.18		0	6	Grey friable calcarenite; relatively tough 6 in. and 9 in. beds and parting between beds 3 ft. 2 in. and 1 ft. 8 in. thick.
		3	2	
		1	8	
		0	9	
		2	2	
	D	0	9	*Glycymeris* shell bed—ferruginous calcarenite.

*The marker beds are designated by letters. They scarcely have the status of members and probably none of them will ever be recognized with certainty anywhere except in the cliff sections described herein.

the point 600 ft. west of Bird Rock where it will be seen in the face of the cliff, 16 ft. above the rock platform.

The distribution of foraminifera in samples from Section 7 is shown in Table VII. The samples are arranged in ascending sequence.

To ensure adequate sampling of the beds between BR.8 and BR.9 a section (No. 8) was measured in descending sequence at the point of the bluff directly above Bird Rock.

SECTION 8

Sample No.	Marker Bed	Thickness ft.	in.	Description
BR.25	—	6	0	Yellow siltstone.
BR.24	—	6	0	
—	N	2	0	
BR.23	—	2	0	Locally prominent concretionary calcilutite.
BR.22	—	4	0	Grey clayey siltstone, decreasingly clayey upwards.
BR.21	—	5	0	
—	M	0	4	Lenticular concretionary calcilutite.
BR.20	—	5	0	Yellow marly siltstone.
BR.19	—	5	6	
—	L		6-12	Calcareous concretions (silty calcareous claystone) 3 to 6 ft. apart.
—	—	5	5	As in Section 7.
—	K	1	7	
—	—	2	6	
—	J	1	1	
—	—	9	0	
—	H	2	0	

It should be noted that the thickness of the beds between the top of "M" and the bottom of "H" is the same in this section as in No. 7. The significance of this will be discussed later (see p. 101).

The distribution of foraminifera in samples from Section 8 is shown in Table VIII. The samples are arranged in ascending sequence.

Between Bird Rock and Fisherman's Steps

The cliffs between Bird Rock and Fisherman's Steps are illustrated in Plate VI, Fig. 2.

There is an anticline between Bird Rock and Fisherman's Steps and, because of this 27 ft. of strata below the lowest beds at Bird Rock are exposed on the axis of the anticline about midway between the two localities. The *Glycymeris* bed ("D" at base of Section 7) crops out at sea level 50 ft. west of Bird Rock and at sea level 80 ft. east of Fisherman's Steps. This bed is easily traced between the localities mentioned and hence forms a convenient marker. Details of the 27 ft. of strata exposed below marker "D" at the axis of the anticline are given in Section 9.

The distribution of foraminifera in samples from Section 9 is shown in Table IX. The samples are arranged in ascending sequence.

The exact spot at which the 70 ft. bore referred to by Chapman (1922a) was put down cannot be identified, but its position is sufficiently well described to indicate that it was commenced in beds immediately below FB.1. Chapman's log of the bore is given in Section 10.

SECTION 9

Sample No.	Thickness ft.	in.	Description
FS.11	–	–	Marker "D".
FB.5	7	9	Average of 7 ft. 0 in. - 8 ft. 7 in. Grey calcarenite; very shelly. In places base is marked by tough band (calcilutite).
FB.4	4	7	Grey calcarenite; very shelly.
FB.3	4	7	Brown calcarenite; few shells.
—	1	0	Calcareous concretions in marly matrix.
FB.2	4	3	Brown and grey carbonaceous shelly calcareous siltstone; green clayey glauconitic pipes common.
FB.1/FB.A	5	3	

SECTION 10

	ft.	in.
Blue marl	23	3
Sandstone [probably calcarenite, H.G.R.]	0	7
Dark green sandy marl	3	2
Greensand	4	0
Dark green sandy marl	5	0
Blue, grey and brown marl	14	0
Brown sandy marl	20	0
	70	0

The fossils identified in the borings are listed in the paper from which the foregoing information is quoted. Chapman's comment on this bore is quoted on p. 82. Sections 7, 9 and 10 together represent a continuous sequence 258 ft. thick.

Fisherman's Steps

This locality is well known; at the time these investigations were made it was marked by wooden steps leading from large talus blocks (which rest on the rock platform) to the mouth of a shallow hanging valley. (See Plate V, Fig. 3.)

Section 11 is that exposed at Fisherman's Steps.

The following notes will facilitate recognition of the individual units in the sequence. The beds from FS.8 downwards form a nearly vertical cliff and were sampled on the north-west side of the wooden steps. The top of the bearer of the steps rests on bed "F", and the *Glycymeris* bed—"D"—crops out on the rock platform 80 ft. east of the steps. The unique lithology (at least 50% shells) and bright red colour of this bed will enable it to be identified very easily.

The higher and generally more friable beds form a steep slope receding landwards above FS.8. The slumped outcrop of FS.7 (bed "G"), rounded outcrop of FS.6 and the markers "H", "J" and "K", provide means of identifying all units in this part of the section.

As the description above indicates there is no difficulty in tracing at least seven individual beds from Bird Rock to Fisherman's Steps, so that correlation between the two is well controlled. (See also Plate VI, Fig. 2.)

The distribution of foraminifera in samples from Section 11 is shown in Table X. The samples are arranged in ascending sequence.

Between Fisherman's Steps and Dead Man's Gully

At a point about half-way between Fisherman's Steps and Dead Man's Gully a section 80 ft. thick is exposed in which certain lithological units occur which can

SECTION 11

Sample No.	Marker Bed	Thickness ft.	in.	Description
		4	0	Soil and clay.
FS.1	K	0	8	Concretionary non-fossiliferous calcilutite; pale yellow on exposed surface.
		3	4	Yellowish grey silty marl.
FS.2	J	0	8-12	Calcilutite; lenticular.
		5	0	Greenish grey marl.
FS.3		4	0	Greenish grey marl.
	H	1	3	Calcilutite; honeycomb weathering; prominent because of weathering away of beds immediately below.
FS.4		5	7	Greenish grey siltstone.
FS.5		6	10	Greenish grey siltstone.
FS.6		3	2	Greenish grey clayey siltstone; rounded outcrop.
FS.7	G	15	0	Grey silty marl; slumped and obscured by talus. FS.7 = bottom 5 ft.
FS.8	F	2	0	Tough — Shelly calcilutite (tough) to calcarenite (friable), small echinoids particularly abundant.
		1	0	Friable
		1	0	Tough
		5	0	Friable
FS.9	E	1	3	Tough — Shelly calcilutite (tough) to calcarenite (friable).
		3	0	Friable
		1	0	Tough
		3	0	Friable
		0	8	Tough
		3	3	Friable
		1	4	Tough
		0	10	Friable
		2	0	Calcarenite.
		3	0	Shelly fine calcarenite.
		1	10	*Glycymeris* shells in ferruginous calcarenite matrix.
FS.10		5	0	Fine calcarenite; tougher and less shelly than bed above.
		2	6	Friable grey fine calcarenite; shelly.
FS.11	D	1	0	*Glycymeris* shells in cemented ferruginous fine calcarenite. Shells make up at least 50% of rock.
Sea level, low tide.				

be traced continuously from Fisherman's Steps. The locality is easily identified as it is the first small indentation (forming a small cove at high water) in the cliff south-west from Fisherman's Steps.

Section 12 was measured at this locality.

Six of the markers that can be traced from Bird Rock to Fisherman's Steps can be identified easily from Fisherman's Steps to the section above described. The prominent bed "X" between "D" and "E" provides additional means of correlation and many beds could be traced from one section to the other if additional correlation ties were desired. Locally the grey calcilutite in FD.1 is especially prominent.

The following details will enable the different units of the section to be readily identified in the field. The samples FD.6 to FD.4 and below FD.1 were obtained on the north-eastern side of the south-west point of the cove. Samples FD.3 to FD.1 were obtained on the south-western side of the south-west point of the cove.

SECTION 12

Sample No.	Marker Bed	Thickness ft.	in.	Description
FD.5, 6, 16	—	25	0	Light grey clayey siltstone, mottled yellow. FD.16 full thickness; FD.5 bottom 1 ft. 4 in.; FD.6 14 ft. 8 in. above FD.5.
	K	0	9	Pale yellow calcilutite.
FD.4, 15	—	3	0	Grey silty marl; mottled light grey.
	J	1	4	Dark grey calcilutite.
FD.3, 14	—	9	6	Yellowish grey marl; gypsum abundant.
	H	1	4	Dark grey calcilutite.
FD.13, 2	—	4	6	Mottled grey clayey marl. FD.13 full thickness; FD.2 top 2 ft.
		–	–	Calcareous concretions.
FD.12	—	3	8	Mottled grey clayey marl; gypsum abundant.
FD.11	—	2	6	Friable grey clayey marl.
FD.1 { FD.10, FD.8	—	6	2	Grey clayey siltstone with dark grey patches; abundant gastropods. FD.10 full thickness; FD.8 bottom 2 ft.; FD.8 upper 4 ft. 2 in.
FD.1		1	3	Grey calcilutite, locally prominent.
FD.1 { FD.7,	G	10	3	Grey silty marl; upper 3 ft. mottled lighter; pencil-like concretions of pyrite.
FD.1 { FD.9		6	0	Calcarenite and fine calcarenite alternating. (Top = horizon of marker "F".)
No change in lithology as compared with Fisherman's Steps, hence no samples.	E	2	0	Calcilutite.
		11	8	Calcarenite; *Glycymeris* sporadically distributed; twinned gypsum crystals common near top.
	X	2	0	Fine calcilutite.
		7	2	Calcarenite.
		0	3	Shelly band, abundant broken *Glycymeris* shells.
		3	4	Calcarenite.
	Y	0	4	Shelly band, *Glycymeris* abundant.
		2	8	Calcarenite.
	D	0	3	*Glycymeris* shell bed.
		3	0	Calcarenite with pipes and lenses of green glauconitic clay.
Beach level.				

Samples FD.7 and 8 were taken on the south-west side of the north-east point of the cove.

The distribution of foraminifera in samples from Section 12 is shown in Table XI. The samples are arranged in ascending sequence.

Dead Man's Gully

Section 13 is that exposed at Dead Man's Gully.

In comparing this section with those to the east thereof, it will be noted that only three of the markers ("J" and "H" and the horizon of "F") traced continuously from Bird Rock may be identified. Bed "K" is present on the eastern side of the cove (FD.), in which Section 12 was measured, but comes to an end about half-way round the cliff above the cove and cannot be identified farther west. Bed "E" can be traced with certainty only about three-quarters of the distance from FD. to Dead Man's Gully. Although bed "D" itself cannot be recognized as a distinct marker its stratigraphical position is not in doubt as a similar *Glycymeris* bed "Y" 2 ft. 8 in. above "D" at locality FD. can be traced from Dead Man's Gully.

SECTION 13

Sample No.	Marker Bed	Thickness ft.	in.	Description
		16	0	Grey silty marl.
	J	0	10	Yellowish brown calcilutite.
		8	10	Yellow sandy marl with nodular calcareous concretions, white on surface.
	H	1	4	Yellowish brown concretionary calcilutite.
DM.4		3	3	Clayey marl.
		0	4-6	Concretionary cream calcilutite—locally prominent, but limited lateral extent.
		3	2	Grey siltstone, mottled yellow.
DM.5		13	0	Grey sandy marl, mottled yellow with concretionary calcilutite 2 ft. from top.
DM.1		9	10	Grey clayey marl.
DM.2		0	6	Shelly band. (Top = horizon of marker "F".)
		2	2	Calcarenite.
DM.3		7	7	Grey calcarenite. Small echinoids abundant.
		3	0	Calcarenite, shelly.
		2	4	Calcarenite, shelly; tougher than bed above.
		3	6	Calcarenite, alternating tough and friable beds.
		0	6	Clayey marl.
	X	1	1	Calcilutite; tough (locally prominent; traceable from Fisherman's Steps).
		3	5	Shelly calcarenite—layer of shells at base.
		1	2	Calcilutite; tough (forms prominent ledge at mouth of gully).
		2	2	Calcarenite.
		1	5	Calcilutite; tough.
		1	9	Shelly calcarenite.
	Y	0	2	*Glycymeris* shell bed.
		6	6	Grey shelly calcarenite with pipes and lenses of glauconite and concretionary lenses of calcilutite up to 20 ft. in length.

The bed "X" which is prominent at locality FD. is easily identified at Dead Man's Gully.

The lower part of the section at Dead Man's Gully is made up of a number of individual units including dense unfossiliferous calcilutite as compared with the generally poorly bedded highly fossiliferous calcarenite in the lower part of the section east of Dead Man's Gully.

The distribution of foraminifera in the samples from Section 13 are shown in Table XII. The samples are arranged in ascending sequence.

Between Dead Man's Gully and Rocky Point

The changes in lithology and the dying out from east to west of the marker beds continue as far west from Dead Man's Gully as details can be observed.

Section 14 was measured at a point 1,200 ft. west of Dead Man's Gully.

Bed "J" is the only marker in the upper part of the section which persists to this point. The dividing surface—top of 1 ft. 1 in. bed of calcareous sandstone—between the upper and lower parts of the section can be identified with reasonable certainty but there are no other correlation controls.

It is not possible to trace any individual bed, in the upper part of the section, between this locality and Rocky Point because the cliff decreases in height and its upper part is covered with scrub.

SECTION 14

Marker Bed	Thickness ft.	in.	Description
	–	–	Yellow silty marl.
J	1	5	Yellowish brown calcilutite.
	41	0	Yellow sandy marl with calcareous nodules (white on surface) in upper portion.
	1	1	Hard grey calcareous sandstone. (Top = approx. horizon of marker "F".)
	1	9	Sandy calcarenite; friable.
	1	0	Grey sandy calcarenite; tough.
	1	8	Sandy calcarenite.
	1	9	Grey calcilutite; tough.
	3	7	Yellowish grey silty calcarenite.
	0	6	Calcilutite; tough.
	2	5	Yellowish grey silty calcarenite.
	15	0	Fine silty calcarenite.

The lower, harder, part of the section can be traced between the two localities, but individual beds are not continuous and there are a few short breaks (one of 200 ft.) in the exposures so that it is impossible to make a close correlation. However, the beds are almost flat and the dividing surface between the upper and lower parts of Section 14 can certainly be identified at Rocky Point wtihin a few feet.

Between Bird Rock and Mouth of Jan Juc Creek

From a point 300 ft. east of Bird Rock the Tertiary beds are covered with sand and soil for a distance of 100 ft. Immediately east of the soil covered area, Section 15 is exposed in the cliffs.

SECTION 15

	Thickness ft.	in.	Description
	27	0	Calcarenite (tough and friable beds of about same grain size alternating); greenish yellow on weathered surface, pale cream when freshly broken.
*	0	4	Off-white sandy calcarenite with echinoids, 2½ in. in diameter.
	24	0	Similar to 27 ft. above.
	30	0	No outcrops; grass covered slope.
	0	9	Calcilutite; serpulae abundant.
	1	6	Grey clayey marl; shelly.
	0	9	Calcilutite; lenticular.
	1	2	Grey clayey marl; shelly.
	0	7	Calcilutite; concretionary.
	1	9	Grey clayey marl with abundant gastropods.
	0	9	Calcilutite; concretionary, shelly.
	5	0	Grey clayey marl.

* Marker "O".

This section was not sampled because a more complete one (Section 17) is available near Jan Juc Creek. It is introduced here for the purpose of discussing correlation with the Bird Rock section.

As mentioned on page 79, Daintree (1863) regarded the limestone (calcilutite) at the top of Section 15 as being above the highest beds exposed at Bird

Rock. Tate and Dennant (1893, 1895) and later Hall and Pritchard (1896) considered Daintree to be in error and they correlated the limestone with the upper part of the Bird Rock section. Later writers (Singleton, 1941, p. 39) have accepted this view. Examination of the cliff face certainly suggests that the limestone is equivalent to the upper part of the Bird Rock section, but measurement shows that the eye is deceived to some extent. There is a slight change of strike and a marked change in amounut of dip between the two exposures, and the face of the cliff is concave seawards; these factors combine to suggest to the eye that the upper beds thin to the west. As pointed out on page 95, comparison of Sections 7 and 8 shows that this thinning does not occur.

An attempt was made to establish the relationship between the sections exposed on each side of the soil covered area. The last identifiable outcrop east of Bird Rock when the locality was first visited during this investigation was bed "M". The nearest reliable dip (on bed "H") to this outcrop on the western side of the soil covered area was 16° on a bearing of 350°. The beds on the eastern side of the soil covered area had a dip 3° on a bearing of 355°. The horizontal distance between the outcrops on either side of the gap normal to the strike was 90 ft. From these measurements it was estimated that the stratigraphical interval represented by the gap is 15 ft. Thus, if there is no faulting the lowest exposure east of the gap is 15 ft. above bed "M". There is support for this conclusion in the general resemblance between the limestones with closely spaced concretions in the lower part of Section 15 and the beds represented by BR.10 - BR.12.

The outcrops mentioned in the foregoing discussion will probably be those mostly commonly exposed but better evidence was obtained early in 1949. At that time storms occurred during a period of extreme high and low tides. As a result slumping took place on the cliff face. This obscured some of the details above referred to, but the hard beds in a total thickness of 46 ft. above marker "H" were exposed and could be examined at low water. (They have been covered again since then.) Moreover, the interval between the highest bed thus exposed and the base of BJ.1 (see Section 17) could be measured and was found to be 23 ft. The direction and amount of dip of the exposed beds was accurately measurable and it was possible to confirm that there is no faulting and that there is a slight change in dip direction from the lowest bed "H"—350°—to the highest bed—355°—accompanied by a gradual change in amount of dip from 16° to 3° respectively.

The section exposed revealed the details given in Section 16.

Section 16

Marker Bed	Thickness ft.	in	Description
N	0	9	Discontinuous nodular calcareous concretions.
	9	0	*
	1	0	Two concretionary limestone (calcilutite) beds separated by more friable strata.
	4	6	*
M	1	0	Limestone (calcilutite)
	14	0	*
K	1	0	Limestone (calcilutite)
	16	0	*
H	–	–	Top of bed "H".

* Not exposed.

These measurements leave little room for doubt that the highest bed exposed by the storms is "N" and, as the position of "N" in Section 17 is known, the relationship between the Bird Rock Section and the limestones east of it can be established. It will be seen by reference to Fig. 7 that these measurements indicate that the limestones of Section 17 are stratigraphically equivalent to part only of the marl and siltstone of the Bird Rock Bluff (Section 7). Thus, although Daintree was wrong in detail he was right in stating that three distinct lithological units are exposed.

The off-white sandy calcarenite (Marker "O") near the top of Section 15 was found very useful in maintaining correlation easterly from Bird Rock. As shown in Section 15 it is 24 ft. above the base of the calcarenite that forms the cliff east of Bird Rock; at the mouth of Jan Juc Creek it is 26 ft. 9 in. above the base of those beds.

Section 17 is a composite one, of the beds exposed between Bird Rock and Jan Juc Creek.

Details of the section may be recognized by reference to the following notes:

BJ.1 - BJ.5 form the bare cliff exposures and the details given were measured at and west from the point where the limestone ledges pass under the sand at the mouth of Jan Juc Creek. (Sometimes exposed and at others covered.)

BJ.6 and BJ.8 were measured at a point about 200 ft. east of Section 15.

BJ.7 was measured 80 ft. east of BJ.6.

The lower part of the section (below BJ.8) is the same as the lower part of Section 15.

The relationship between this Section and that at Bird Rock is discussed above.

The distribution of foraminifera in samples from Section 17 is shown in Table XIII. The samples are arranged in ascending sequence.

Jan Juc Creek to Spring Creek

The first outcrops east of the mouth of Jan Juc Creek so closely resemble those to the west of it that the section was not measured in detail or sampled. These outcrops form a cliff 460 ft. long and 30 ft. high. The off-white sandy calcarenite marker "O" is clearly defined 5 ft. from the top, and at this point is 24 ft. above the top of a ledge-forming calcarenite bed 10 in. thick, which, therefore, may reasonably be correlated with the calcarenite one foot thick at the base of BJ.1 in Section 17.

Cemented cross-bedded calcareous sands of late Tertiary to Sub-Recent age form the cliff front for 1,000 ft. east of the outcrops referred to in the preceding paragraph. At this point—at dead low water—the ledge-forming calcarenites, which form the lower part of the section on both sides of Jan Juc Creek, are exposed. The higher beds are a slightly different facies from that represented by the BJ. samples. Bedding planes are poorly defined and the rock is fairly generally a friable, yellow, silty calcarenite with some discontinuous relatively well-cemented thin beds of calcilutite. (See Plate VI, Fig. 3.)

Section 18 was measured in descending sequence at and near the old wooden steps on the southern side of Jan Juc Point.

The distribution of foraminifera in samples from Section 18 is shown in Table XIV. The samples are arranged in ascending sequence.

SECTION 17

Sample No.	Marker Bed	Thickness ft.	in.	Description*
—	—	9	6	Calcarenite (type a). Note: all calcarenites in this section are greenish yellow on weathered surface and pale cream on broken surface.
BJ.5	—	13	0	
BJ.4		4	6	Calcarenite (type b); echinoids abundant at top.
	O	1	1	Off-white sandy calcarenite.
		1	1	Calcarenite (type b); echinoids common.
		2	1	Calcarenite (type b).
		0	2	Calcarenite (type a).
BJ.3		2	4	Calcarenite (type b).
		1	2	Calcarenite (type a).
		3	8	Calcarenite (type b); nodular calcilutite concretions common.
		1	0	Calcarenite (type a).
BJ.2		5	2	Calcarenite (type b).
		1	0	Calcarenite (type a).
		1	2	Calcarenite (type b).
		0	10	Calcarenite (type a).
BJ.1		1	9	Calcarenite (type b).
		0	10	Calcarenite (type a).
		3	6	Calcarenite (type b).
		1	0	Calcarenite (type a).
		1	10	Yellow clayey marl.
		0	10	Calcarenite.
		2	4	Yellow sandy marl with calcareous nodules.
BJ.6		0	9	Calcarenite.
		2	10	Yellow sandy marl with calcareous nodules.
		0	3	Calcarenite.
		8	0	Grey clayey marl.
BJ.7		0	5	Calcilutite.
		0	9	Grey clayey marl.
BJ.8		0	5	Calcilutite.
		2	0	Grey clayey marl.
		1	6	Grey clayey marl.
	N	0	9	Calcilutite; lenticular.
		1	2	Grey clayey marl; shelly.
Not Sampled		0	7	Calcilutite; concretionary.
		1	9	Grey clayey marl with abundant gastropods.
		0	9	Calcilutite, concretionary, shelly.
		5	0	Grey clayey marl.
		–	–	Beach.
	Thickness	87	6	

* Calcarenite (type a) well cemented, rough.
*Calcarenite (type b) friable, silty, argillaceous.

Spring Creek to Yellow Bluff

Spring Creek marks the southern end of the Torquay surfing beach. There are outcrops of calcarenite and clayey marls at the northern end of this beach—i.e. on the southern side of Point Danger—on the northern side of Point Danger and on the point (Yellow Bluff) at the northern end of Zeally Bay which clearly are generally to be correlated with the section at Jan Juc Point. However, as the beds at Jan Juc Point are almost horizontal and those on the southern side of

SECTION 18

Sample No.	Thickness ft.	Description
T.7	5 - 15	Yellow and grey clay. Erosion surface:
T.5	5 - 11	Friable yellow sandy calcarenite, some relatively hard lenticular shelly beds.
T.4	8	
T.3	8	
T.2	6	
T.1	7	Yellow sandy calcarenite, bedded and shelly at base.
—	6	Beach—no outcrop.
T.8	8	Shelly calcarenite; some relatively hard thin beds forming ledges (exposed at dead low water).

Point Danger dip at angles up to 10°, precise correlation between them would only be possible on the basis of some reliable lithological criterion, or on palaeontological evidence. Neither method has given sufficiently precise results for our present purpose. The calcarenite on the northern side of Point Danger contains large numbers of well-preserved tests of *Operculina*.

Anglesea to Airey's Inlet

From Point Roadknight, which consists of Sub-Recent cemented cross-bedded sands, to Urquhart's Bluff—a distance of 3 miles—there are few outcrops of the Tertiary beds. At low tide reefs are exposed between these localities which are composed of the same rock as Point Roadknight. They are mentioned solely because for considerable distances they have a strike and dip parallel to the regional strike and dip, are inclined at angles up to 10°, and might therefore be mistaken for Tertiary strata.

At Urquhart's Bluff, the outcrop consists of volcanic agglomerate, and it is important to determine the relationship of these rocks to the Anglesea section.

The slope of the surface between the Anglesa boat harbour and Urquhart's Bluff is fairly certainly a dip slope. The outcrops in road cuttings and gullies between these two points are poor but the rocks exposed closely resemble the lighter-coloured marine beds in the upper part of the section at Anglesea. In the road cutting above Urquhart's Bluff yellowish-grey to purple sandy clays and one prominent yellowish-brown sandstone bed 18 in. thick are exposed. These beds overlie the agglomerate at Urquhart's Bluff. It seems reasonable to conclude that the yellowish-grey to purple clays represent the uppermost clays (W.102) at the Anglesea boat harbour, that the yellow sandstone represents W.101, and that the volcanic agglomerate at Urquhart's Bluff may be correlated with the clastic volcanic rocks at and near Soapy Rocks.

Volcanic rocks, dominantly basaltic tuff, breccia or agglomerate crop out continuously from Urquhart's Bluff to Split Point and may be examined both on the rock platform and in cliff sections up to 50 ft. high. These beds show marked cross-bedding, a detailed examination of which may throw some light on the position of the crater from which the volcanic ejectamenta were derived; as remarked by Hall (1910) it could not have been far distant—the extent of the volcanic rocks is limited, and boulders up to four feet in diameter are present in large numbers. The thickness of the volcanic rocks cannot be determined accurately as their base is not exposed but it is not less than 50 ft. This thickness is exposed below the

limestone (described below) in the cliff below the camping ground near "Sunnymeade" house. This locality, shown on the military map (Anglesea sheet) is about 1¼ miles north of Split Point.

At Split Point and Table Rock remarkable sections are exposed showing limestone (calcarenite) resting upon volcanic agglomerate. Krause (1874, p. 100) refers to these. The upper surface of the volcanic rocks in most places is marked by a bed of boulders—one boulder thick—derived from the agglomerate. In places the boulder bed is absent, and at one locality at least—¼-mile north of Eagle Rock—12 ft. of well-bedded coarse quartz sandstone occurs between the boulder bed and the overlying limestone. There is an excellent exposure at the foot of Table Rock showing shelly marl and limestone resting on an irregular surface of agglomerate. In places, hollows in the agglomerate several feet deep are filled with masses of shells. Hall (1910) referring to these exposures wrote: "the surface of the underlying basalt is cut by channels and is very bouldery, so that the limestone forms deep pockets . . . some of these pockets go down to 20 ft. below the main mass".

Section 19 was measured and sampled at Split Point, opposite Table Rock. A track leads down the cliffs to this locality at a point about 660 ft. south-west of the lighthouse.

SECTION 19

Sample No.	Thickness ft.	Description
A.11	13	Calcarenite; types (a) and (b)* alternating.
A.10	4	Calcarenite; type (a); flat echinoids.
	4	Calcarenite (quartzose); type (b); flat echinoids.
A.9	6	Quartzose calcarenite; type (b); small echinoids abundant.
—	10	
A.8	2	
A.7	8	
A.6	6	Calcarenite; types (a) and (b) alternating.
A.5	4	Quartzose calcarenite; type (a).
A.4	6	Shelly calcarenite; type (a).
A.3	6	Shelly calcarenite; type (a).
A.2	6	Calcarenite; type (a).
—	–	Volcanic agglomerate.
Thickness	75	

*For definition see p. 103.

The distribution of foraminifera in the samples from Section 19 is shown in Table XV. The samples are arranged in ascending sequence.

Airey's Inlet to Eastern View

Between the mouth of Airey's River (Painkalac Creek) and Eastern View there are no cliff sections and the exposures in the creek beds and road cuttings are discontinuous. When the Great Ocean Road was first cut some good sections were probably available for examination, but most of these are now partly obscured. However, the exposures in this locality are notable because they reveal the only known natural sections in the whole of the coastal region east of Cape Otway of the lowest part of the Tertiary sequence.

Hereunder notes are given about the outcrops between Eastern View and Airey's Inlet from west to east, i.e. in ascending stratigraphical sequence.

On the beach exposed at low tide between Spout Creek and Coalmine Creek, coal measures are exposed overlying Jurassic greywacke. The underwater outcrops of the coal seams show out very clearly in air photographs (Plate IV, Fig. 1). Krausé (1874) recorded an outcrop exposed at low water opposite the mouth of Spout Creek (his plan No. 3). This is now covered with sand. Section 20 was measured between Spout Creek and Coalmine Creek.

SECTION 20

Thickness ft.	in.	Description
2	0	Lignite.
16	8	Ferruginous fine conglomerate.
2	4	Lignite (dip 120° at 35°).
4	7	Ferruginous fine conglomerate and sandstone.
1	9	Lignite.
27	6	No outcrop.
3	0	Lignite with large pieces of wood.
21	10	No outcrop.
3	5	Lignite.
58	6	No outcrop.
2	0	Lignite.
40	2	Ferruginous coarse sandstone.
66	0	No outcrop (pebbly coarse sandstone in Coalmine Creek).
–	–	Greywacke—Jurassic (dip 115° at 41°).
249	9	

When Krausé (1874) visited the locality, prospecting for coal was in progress in Stony (now Coalmine) Creek. Signs of this can still be seen 115 ft. upstream from where the Great Ocean Road bridge spans the creek; a further 50 ft. upstream Jurassic greywacke is exposed. Combining measurements of natural exposures with information obtained from shafts and a bore, Krausé compiled Section 21 (his Section No. VI).

Krausé's section gives details of the beds not exposed in the lower part of Section 20. Precise correlation between Sections 20 and 21 cannot be made but the lowest seam in Section 20 is possibly represented in Section 21 by the 1 ft. 8 in. of brown and black clay, in part bituminous (74 ft. from top).

Krausé shows a slight unconformity between Jurassic and Tertiary. The dips he gives are respectively 26° on a bearing of 130° and 22° on a bearing of 120°. The authors' observation is that both dip approximately at 32° on a bearing of 130°.

On the north side of the Great Ocean Road 30 ft. east of the bridge over Coalmine Creek purplish grey clayey siltstone is exposed in a small pit. The siltstone closely resembles some of the higher marine beds at Anglesea but it contains no fossils.

At the top of the hill immediately behind a private house on the Great Ocean Road named Bills-o-Jacks* a partial section (Section 22) was exposed by a washaway during heavy rains in October, 1949.

*First house on west side of "Great Ocean Road" pergola.

SECTION 21 (After Krausé)

Thickness ft.	in.	Description
10	0	Ironstone and conglomerate.
40	0	Soft white and yellowish sandstone with bands and layers of harder ferruginous sandstone.
18	0	Yellow brown and red clay with ironstone nodules.
6	0	Soft yellowish-white sandstone with round pieces, sulphate of iron.
0	3	Dark brown clay.
0	8	Black bituminous sandy clay.
0	9	Dark brown clay.
22	0	Soft grey-white sandstone, the upper portion with carbonaceous fragments.
9	6	Fine white sand.
11	8	Yellow and brown siliceous sand.
9	6	Hard sandstone-grit.
5	3	Grey foliated micaceous soft sandstone with leaf impressions.
15	0	White coarse sand bed.
7	4	Yellow and grey sandy clay.
6	0	Shaley lignite.
3	0	Good strong brown coal rich in carpolithes.
5	0	Shaley lignite showing dicotyledonous structure.
2	8	Soft brown sandy shale which sustains a flame.
1	6	Woody brown coal.
9	0	Sandy clay.
10	6	Grey soft sandstone.
5	3	Loose sand.
5	3	Greyish-white clay.
15	6	Brown clay.
5	0	Sandy shale with sulphate of iron.
224	7	
		Mesozoic sandstone.

SECTION 22

Sample No.	Thickness ft.	in.	Description
	6	6	Yellowish brown friable laminated sandstone.
	0	2	Reddish brown friable sandstone (dip 130° at 25°).
EV.5	14	6	Light buff fine friable sandstone. Colour changes to light brown at base. Ferruginous concretions up to 3in. in diameter, 2 ft. above base.
	2	3	Dark brown to black lignite with laminae of fine sand, grading down into—
EV.4	2	0	Brown silty fine friable sandstone with some mica.
	4	0	Light brown fine friable sandstone with some mica.
EV.3	1	6	Light brown fine friable laminated sandstone.

No fossils were found in the samples taken.

Measurements in the field and examination of air photographs suggest that the lignite seam in this section is the one third from the top in Section 20.

The same heavy rains that exposed Section 21 gouged out the gutter on the north side of the road leading uphill from Bills-o-Jacks and exposed white fine silty

sandstone and a coal seam between the bottom of the hill and the first bend in the road.

At the top of the hill behind the Eastern View Hotel a partial section (Section 23) is exposed.

SECTION 23

Sample No.	Thickness ft.	in.	Description
	1	0	Silty sandstone.
	0	6	Silty sandstone; platy ferruginous layers along bedding planes.
EV.7	8	0	Grey silty sandstone.
	1	0	Concretionary ferruginous layer.
	19	0	Grey silty sandstone.
	6	0	Grey medium quartz sandstone—mottled yellow and brown.
	0	0½	Ironstone.
	0	6	Grey silty sandstone.
	4	6	Mottled grey brown and yellow medium sandstone with ferruginous layers at base.
EV.6	30/40	0	Grey clayey sandstone; ferruginous platy layers.

This section provides some details of beds which clearly are above the observed coal seams but its stratigraphical position cannot be determined accurately. No fossils were found in the samples taken from these beds.

On the east bank of Mogg's Creek adjacent to the downstream side of the Great Ocean Road bridge, a section about 10 ft. thick of pale red-purple silty sandstone and ferruginous coarse sandstone with carbonaceous fragments was exposed in March, 1948. (This section was covered with sand when the locality was visited early in 1949, in October 1949, and in October 1950.) Similar beds may be seen, however, on the north side of the Great Ocean Road between 360 and 540 ft. east of the bridge over Mogg's Creek; they dip at 30° on a bearing of 350°. *Cyclammina* is abundant in the silty sandstone. The thickness of the beds exposed in 1948 is at least 100 ft.

In road cuttings 0·67 mile and 0·8 mile east from Mogg's Creek dips of 13° on a bearing of 110° and 4° on a bearing of 100° respectively were noted. *Cyclammina* is present in the silty sandstone exposed.

Three hundred feet west of a small creek 1 mile east of Mogg's Creek (½ mile west of Airey's River) 40 ft. of very pale red-purple siltstone with thin beds of coarse sandstone are exposed. These beds dip 3° on a bearing of 85°. Two hundred feet west of the same creek a partial section (Section 24) was measured in April, 1949.

SECTION 24

Thickness ft.	in.	Description
16	6	Medium quartz sandstone with layers of coarse quartz sandstone and grey clay up to 3 in. thick.
7	2	Red and grey clay. (Acid ashstone (Dallwitz, 1954).)
10	0	Medium quartz sandstone with layers of coarse quartz sandstone up to 3 in. thick.

The beds dip 3½° on a bearing of 80°; they are unfossiliferous.

At the western end of the Great Ocean Road bridge over Airey's River (Painkalac Creek) about 45 ft. of clays and coarse sandstone are exposed which dip

4° on a bearing of 195°. They contain no fossils. The base of this exposure is 10 ft. above sea level and the beds therefore must underlie the limestone (Section 19) at the mouth of the river.

The fragmentary information obtained in the field and described above has been supplemented by examination of air photographs, mainly with the object of seeing whether the observations made on the structure of the beds exposed between Eastern View and Airey's River are sufficiently reliable to form a basis for calculation of thickness. It has been concluded that they are. The probable thickness of the beds exposed is therefore:

4. 70+ ft.—Sandstone and clay; acid ashstone noted in one place. No fossils.
3. 1,200 ft.—Siltstone with some sandstone; *Cyclammina* abundant.
2. 1,200* ft.—Sandstone; no fossils.
1. 300 ft. (292 ft. 2 in.)—Jurassic Coal Measures.

Definition and Description of Rock Units

In the previous part of this paper the sections exposed between Torquay and Eastern View have been described. Those descriptions were given without regard to stratigraphic classification based on lithology or time. In this part of the paper the data presented are examined and the rock and time-rock (time-stratigraphic) units defined. The columnar sections (Fig. 7) provide a summary not only of the stratigraphic data, but of the correlations outlined in the previous section of the paper.

In considering the names of lithological units and the definition of time-rock units the necessity as far as practicable, to retain old names, and at the same time to conform to the principles of the Australian Stratigraphic Code (Raggatt, 1950) has been carefully observed. To satisfy these two conditions is not easy.

The broad lithological classification of the sediments is a simple exercise in the application of the principles of the Code. If the problem were merely to name and define the lithological units and discuss their age in relation to an established time scale there would be no difficulties. However, these difficulties arise through attempting to relate the name of lithological units to time-rock terms, some of which have been defined by reference to sections exposed in the area dealt with in this paper. Particular difficulties are introduced because:

(i) Two time-rock terms ("Anglesean" and "Janjukian") have been described by reference to sections in the area described. If possible, therefore, it is desirable to choose major rock unit names so that "Anglesean" and "Janjukian" can be related to the names chosen. This is in conformity with classical procedure—that followed, for example, in naming most of the Systems.

(ii) "Anglesean", "Janjukian", "Batesfordian" and "Balcombian" were all defined without relation to each other.

(iii) Although the whole of the section exposed at the type localities was nominated by their authors as "Janjukian" and "Balcombian" the faunal criteria suggested as diagnostic of the Stages as a whole are based on fossils collected predominantly from only part of the type sections. (Tate and Dennant, 1895; Singleton, 1941, pp. 27 and 39.)

*Erroneously recorded as 1,730 ft. in Raggatt and Crespin (1952).

(iv) The relationship between "Janjukian" and "Balcombian" has been confused by bringing into the discussion palaeontological criteria from beds not demonstrably referable to either.

The difficulties thus introduced by errors in concept and procedure are increased by errors in observation:

(i) The limestone at the top of the type "Janjukian" (i.e. between Torquay and Bird Rock) has been correlated with the limestone near its base (at Rocky Point). It is only after repeated reading of the earlier papers on the background of some knowledge of the locality that it is realized that all the previous workers who expressed an opinion on this point made the error of correlating the highest limestone in Daintree's (1863) section with the limestone at Rocky Point. (Relevant references are: Tate and Dennant 1893, p. 211; Hall 1910, p. 50; Singleton 1941, p. 38.)

(ii) It has not been recognized that in the coastal sections exposed between Eastern View and Torquay, the sequence of Tertiary formations in ascending order is: (a) Coal measures, (b) non-fossiliferous sandstone, (c) *Cyclammina*-bearing siltstone and greywacke, (d) dominantly fresh water sediments and volcanic rocks, (e) highly fossiliferous limestones (calcarenites) and (f) marls and siltstones much less fossiliferous than (e).

Before naming the lithological units in the lower part of the sequence it is necessary to determine as precisely as possible the meaning given to "Anglesean" and "Janjukian".

Singleton introduced the name "Anglesean" in 1941. On p. 24 he stated: "Here proposed for the black sandstone and sandy clays of the coastal cliffs . . .", and p. 25 ". . . the interval of time represented by the deposition of the dark coloured sands with *Cyclammina*, of the cliff sections . . .". On p. 13 he implies that he regarded the beds with lignite as a facies of the *Cyclammina sands;* he wrote that underlying the type marine Janjukian "in turn are the so-called lignite beds, . . . they outcrop as dark carbonaceous sand with *Cyclammina* . . .". His statement on p. 69 makes this a little clearer. He wrote: ". . . the richly fossiliferous Janjukian beds are underlain by strata, probably referable to the Anglesean, which in some cases contain *Cyclammina* and are often lignitiferous towards the base". In his Fig. 11, p. 65, he shows a lignite bed about the middle of the Anglesean. In making some of these statements Singleton was possibly influenced by Hall's comment, ". . . between Point Castries and Airey's Inlet [i.e. at Eastern View—H.G.R.] occurs a series of beds which are clearly of Tertiary age but whose relationship to the beds farther east has been a matter of doubt. They have been described in some detail by Krausé, since close to the Jurassic they contain lignite seams . . . . It seems almost certain that these western beds represent the black beds of Anglesea and are of freshwater origin." (Hall, 1910, p. 50.) That is, Hall regarded the Coal Measures at Eastern View as a facies of the black beds with *Cyclammina* at Anglesea.

Singleton's placing of the upper limit of the "Anglesean" at the top of the "black sands" at Anglesea was more or less accidental, and due to the fact that in his early work he did not recognize either the nature of the contact between the "black sands" and the overlying beds, or the close lithological and palaeontological similarity of the overlying beds to the "black sands". Later he noted that the "Janjukian" rested conformably on the "Anglesean" (note from O. P. Singleton to E. S. Hills), so that we may reasonably assume that in his later years his interpretation of the succession was not very different from that given in this paper.

Bearing in mind the objective of trying to name a rock unit so that "Anglesean" can be related to it as a Stage name, definition and usage allow of three ways of using "Anglesea" in the name of a rock unit:

(a) strictly as originally proposed by Singleton,

(b) as the name of all the beds with *Cyclammina* at Anglesea,

(c) to include all the Tertiary beds below the base of the "Janjukian".

Reference to the discussion on pages 131-136 shows that the stratigraphic interval represented by (c) is Palaeocene to Middle Eocene, so that this cannot be adopted. Usage (b) would be better than (a) because its upper contact is with marine beds of determinable age, but otherwise it is open to the same general objections as (a), namely (i) its base rests upon unfossiliferous sediments, and (ii) it contains no fossils of age significance.

For these reasons "Anglesea" has been retained as the name of a rock unit strictly as proposed by Singleton, but it is suggested that the term "Anglesean Stage" should be abandoned and new Stages in the pre-Janjukian sequence defined when adequate evidence is available. It may be noted that Singleton (1941) himself stated that the section at Demon's Bluff was "by no means ideal as a type".

The type "Janjukian" as defined by Hall and Pritchard (1902) and by Singleton (1941) includes all the beds in the Torquay-Rocky Point cliff sections. This name is so widely used in the literature that it is desirable to retain it if possible.

Although all the beds exposed in the cliffs between Torquay and Rocky Point were named "Janjukian" the faunal criteria used for identifying the "Janjukian" are based largely on a knowledge of the shelly fossils from the lower 60 ft. of the section (see p. 80 for statement quoted from Tate and Dennant, 1895; Singleton, 1941, p. 39). The lower half is not only much more fossiliferous than the upper half, but it is easily accessible in many places, whereas the upper half is not. Palaeontological criteria have been confused also, as noted above, by the error made in correlating the limestones at Rocky Point with those at Torquay.

The shelly fauna of the type "Balcombian" occurs mainly in three feet in the middle of the section (Singleton, 1941, p. 27).

It is shown later in this paper that the microfauna of the upper part of the section nominated as "Janjukian" by Hall and Pritchard and by Singleton (Torquay Group of this paper) is characteristically "Balcombian", and therefore that "Janjukian" and "Balcombian" as originally defined overlap each other; both must, therefore, be re-defined.

It is proposed to name the lower beds in the Torquay-Rocky Point Section the Jan Juc Formation and to define Janjukian in relation thereto. Names are proposed also for the lithological units in the upper beds of the Torquay-Rocky Point Section.

The rock units defined and described are:*

Torquay Group {
- Puebla Formation
  - Zeally Limestone Member
- Jan Juc Formation
  - Point Addis Limestone Member

}

- Demon's Bluff Formation
  - Angahook Member
  - Addiscot (Greywacke) Member
  - Anglesea (Siltstone) Member
- Boonah Sandstone
- Eastern View Coal Measures

*These have been approved by the Victorian members of the A.N.Z.A.A.S. Committee on Stratigraphic Nomenclature.

In the table above, the formations are placed in their normal stratigraphic sequence. They are described in the reverse order, i.e. commencing with the oldest.

Eastern View Coal Measures

This name is applied to the Coal Measures at the base of the Tertiary sequence exposed in the coastal sections described in this paper. The Coal Measures rest on the Jurassic and are overlain by sandstone (Boonah Sandstone) in which no fossils have been found. It is difficult to define the upper limit of the Coal Measures precisely because neither the Coal Measures nor the overlying Boonah Sandstone form good outcrops. In interpreting bore logs the upper limit has been placed at the top of the highest coal seam.

The type locality is Eastern View, the only place in the coastal strip described in this paper where details of the formation can be seen in outcrop. Sections 20 and 21 combined as suggested on p. 107 are designated as the type. The thickness there exposed is about 300 ft. (292 ft. 6 in.).

Between Anglesea and Torquay the Coal Measures have been penetrated by several bores. The information thus available is summarized hereunder:

ANGLESEA. South Australian Oil Wells No. 1 bore, Parish of Angahook, proved a minimum thickness of 274 ft. below 188 ft. from surface and No. 2 bore a minimum thickness of 162 ft. below 580 ft. from surface. There is no evidence that either bore reached the Jurassic. Three seams of brown coal were reported in No. 1 bore and two in No. 2 bore. Logs of these bores are held in the office records of the Mines Department of Victoria.

POINT ADDIS. Bore No. 6, Parish of Jan Juc, proved 133 ft. of the Eastern View Coal Measures below 708 ft. 1 in. The driller's log is:

ft.	in.	
1	2	Shale, brown ligneous* (probably coal seam, cf. Jan Juc No. 5 Bore).
19	0	Sand, fine fossiliferous, pyritic.
2	0	Sand, cemented.
3	0	Shale, brown ligneous* (probably coal seam, cf. Jan Juc No. 5 Bore).
60	3	Sand, fine, hard cemented, pyritic with mica.
38	6	Sand, cemented.
1	0	Sand cemented with very hard band.
9	0	Sand, drift.
133	11	

*Should be "lignitic"; "ligneous" has an entirely different meaning.

BIRD ROCK-TORQUAY. The Coal Measures can be identified in the logs of Jan Juc Bores Nos. 2-5 (D.M.V. 1938). They proved the following thicknesses:

No. 2 — 79 ft. — top at 807 ft.
No. 3 — 134 ft. — top at 708 ft.
No. 4 — 112 ft. — top at 603 ft.
No. 5 — 102 ft. — top at 592 ft.

The driller's log of No. 3 Jan Juc is almost word for word a repetition of the log of No. 6 quoted above. Two seams of brown coal were logged in No. 2 and No. 5 bores and one in No. 4.

At Coalmine Creek the Coal Measures can be seen in close proximity to the underlying Jurassic bedrock. Krausé (1874) shows a small angular unconformity between the two (see p. 106) but the differences in dip and strike which he records are no greater than the differences observed between outcrops of Jurassic rocks in the neighbourhood. If there is an angular unconformity at this locality it can only be slight. Examination of the nearby outcrops and of air photographs suggests that the Tertiary and Jurassic beds are conformable, or nearly so, for at least six miles east of Coalmine Creek. In air photographs the Eastern View-Jurassic contact can be identified from the beach near the mouth of Spout Creek through Coalmine Creek at 0·4 mile from its mouth, in Mogg's Creek at 0·8 mile from its mouth to "The Glen", thence up the bed of Distillery Creek and beyond in a general north-easterly direction as far as Anglesea River. Parallel to this the outcrop of the silty sandstone near the base of the Demon's Bluff Formation (which crops out near the Mogg's Creek bridge—see p. 108) can be traced from Mogg's Creek to a point about one mile north-east of Painkalac Creek.

A clear contact between the Coal Measures and the Boonah Sandstone has not been seen, but the similarity in the lithology of the two formations suggests a gradational relationship.

Boonah Sandstone

This formation is defined as the sandstone between the top of the Eastern View Coal Measures and the base of the Demon's Bluff Formation, i.e. between the top seam of the Coal Measures at Eastern View and the siltstone with *Cyclammina* at Mogg's Creek; these are the only outcrops known. The thickness of the Sandstone in this locality is estimated to be not more than 1,200 ft. The name of the formation is taken from the name of the parish in which the outcrops occur.

It is thought that the whole of the formation is much like the partial section (No. 23) exposed at the top of the hill behind the Eastern View Hotel. Most of the sandstone is loosely cemented and this no doubt accounts for the fact that it makes poor outcrops.

The logs of the many bores drilled at Anglesea and Torquay are not sufficiently detailed to enable the Boonah Sandstone to be identified. Chapman and Singleton (1925) noted *Cyclammina* in a sample from Jan Juc No. 3 bore only 68 ft. above the highest coal seam, so that the formation, if present, is evidently much thinner at Torquay than at the type locality.

Demon's Bluff Formation

The Demon's Bluff Formation is defined as the sediments and volcanic rocks between the top of the Boonah Sandstone and the base of the Jan Juc Formation. It consists chiefly of siltstone, greywacke, minor loosely cemented coarse ferruginous quartz sandstone, and layers of thin beds of quartz pebbles. At Anglesea and Airey's Inlet volcanic rocks are interbedded with the uppermost sediments. The sediments range in colour chiefly from brownish black to red-purple, and they usually are characterized by abundant filled worm burrows and algal (?) remains. Almost any sample from the main part of the Formation contains *Cyclammina* and this foraminifera commonly occurs in great abundance. Other fossils are scarce.

The only complete natural section is provided by the exposures between Mogg's Creek and Airey's Inlet in the Parish of Boonah (Sections 22 to 24), but the best-known partial sections are in the Parish of Angahook (Sections 1 to 3). Measurements made in the type locality suggest that the Formation has a thickness of about 1,300 ft. The records of boring at Anglesea, Point Addis and Torquay

indicate that the Formation maintains the lithological features observed in outcrop over the whole coastal strip described in this paper. These borings also provide some useful information on the thickness of the Formation.

In referring to the Jan Juc Nos. 1-5 bores Chapman and Singleton (1925, p. 996) state:

"At Torquay recent borings in search of oil prove the deepest beds yet reached to consist of lignitiferous sands with the foraminifera *Cyclammina*; the range of this series, from the data at present available, being approximately between 840 and 410 feet below sea-level. At a depth of 170 feet below sea-level the beds consist of the typical greensands and marls which are exposed in the Bird Rock cliffs. An earlier boring near Bird Rock penetrated this latter series to a depth of 70 feet, and a detailed examination of the material by one of us (F.C.) showed no notable variation from the fauna and lithology of the Bird Rock series."

From investigation in the field and examination of bore data it was apparent that there must be errors in this statement.

We are indebted to Mr. W. Baragwanath and Dr. D. E. Thomas who, by searching Victorian Mines Department records, have cleared up the doubtful points. These records show that the bore referred to is No. 3 and that the statement should be corrected as follows:

"At Torquay . . .; the range of this series, from the data at present available, being approximately between *640* and 410 ft. below *the surface at No. 3 bore*. At a depth of 170 ft. *in this bore* the beds consist of the typical greensands and marls which are exposed in the Bird Rock cliffs."

This note by Chapman and Singleton shows that the top of the Demon's Bluff Formation was intersected between 170 ft. and 410 ft. in No. 3 bore and its minimum thickness is therefore about 230 ft.; actual thickness may be 320 ft. (See Fig. 4.)

The logs of the Point Addis bores (Jan Juc 6 and 7) provide some information on the thickness of the Formation. Taking into account its position in relation to the cliff exposures nearby, No. 6 bore could not have penetrated much more than 115 ft. of the strata overlying the Demon's Bluff Formation and possibly its top immediately underlies the bed designated "limestone band, hard", logged at 140 ft. This bore intersected the top of the Eastern View Coal Measures at 708 ft., so that the thickness of the Demon's Bluff Formation plus the Boonah Sandstone is not greater than 568 ft.

No. 7 bore would have passed into the top of the Demon's Bluff Formation at about sea-level. Its collar is about 70 ft. above sea-level so that possibly the bore entered the Formation at 91 ft.—"Sand, cemented". If so, this bore was in either the Demon's Bluff or the Boonah Sandstone for a bore depth of at least 600 ft. (a true thickness of 580 ft.).

The two bores put down by South Australian Oil Corporation Limited at Anglesea provide useful information. Logs were made available for examination by courtesy of the Company and the Victorian Mines Department. The horizon at which No. 2 bore commenced cannot be determined reliably, but the log suggests that it commenced in the Demon's Bluff Formation (it was certainly in the Formation at 40 ft.) proving a thickness for the Demon's Bluff Formation plus the Boonah Sandstone of not less than 580 ft. At 366-439 ft. the driller logged "brown clay—beds of fossil shells" and at 446-472 ft. "more fossils". Among the fossils found at 366-439 ft. F. Chapman identified *Jouanetta cuneata* and *Turritella* sp. This is an unusual record, as shelly fossils are extremely scarce in the outcrops of the Demon's Bluff Formation. The shells identified by Chapman cannot be found.

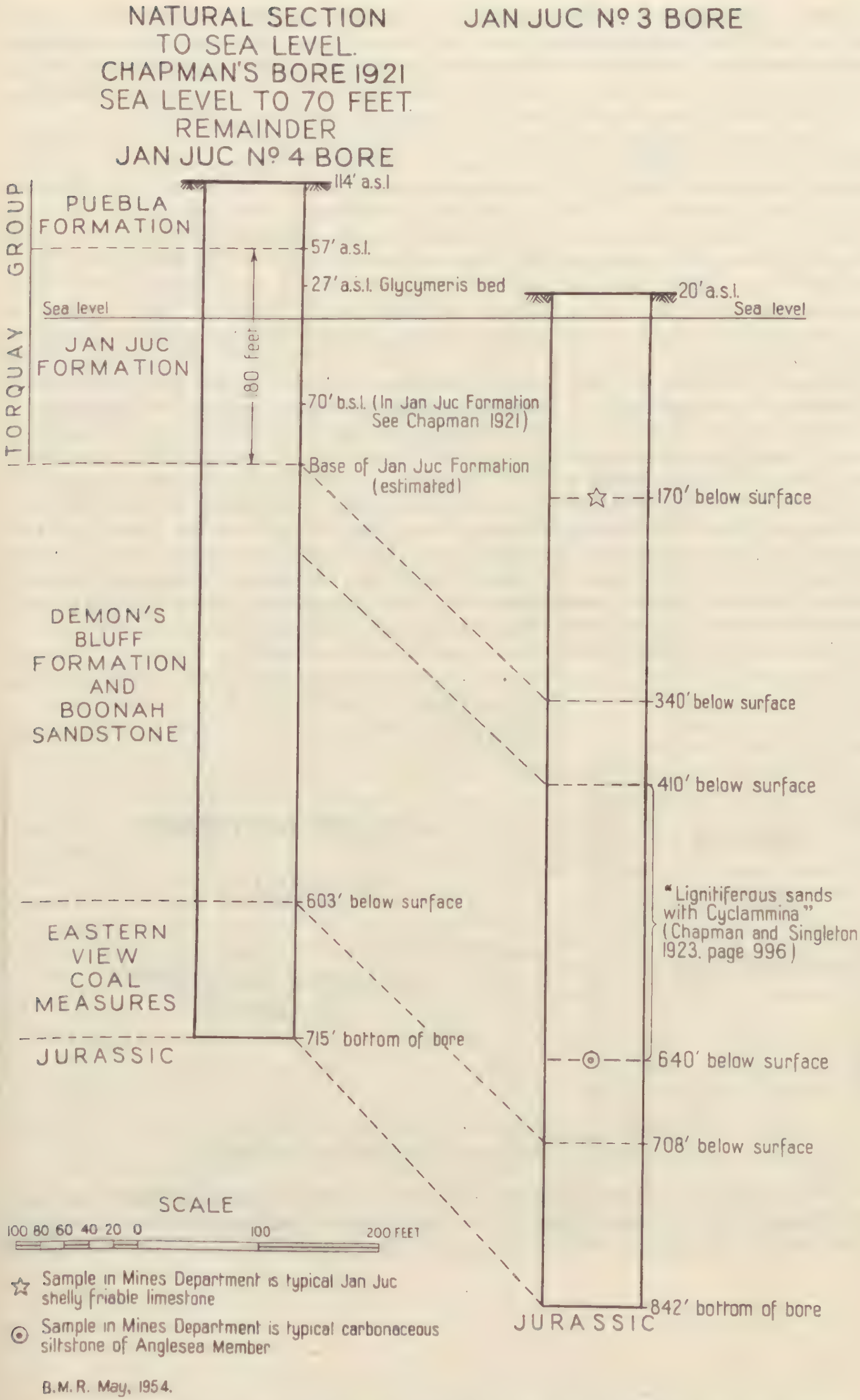


Fig. 4.—Correlation between Chapman's Bore (1921), Jan Juc No. 3 and Jan Juc No. 4 Bores.

Between Anglesea and Bell's Headland the Demon's Bluff Formation consists of two well-defined members (described below). These are essentially greywacke and siltstone ranging from deep brownish black at the base through pale red-purple to yellowish grey at the top. The colour is due to finely divided organic (carbonaceous) matter, most of which can be removed by repeated washing.

The volcanic agglomerate and coarse sandstone (exposed between Urquhart's Bluff and Airey's Inlet) and the volcanic rocks and interbedded sediments exposed at and adjacent to Soapy Rock, Anglesea, are included as a member of the Demon's Bluff Formation for the following reasons. The volcanic rocks are known to occur only over a limited area and are interbedded with sediments which have a lithological affinity with the underlying beds and are sharply distinguished from those above. The volcanic rocks and the sediments with which they are associated were deposited at the same time as marine sediments of the Demon's Bluff Formation.

Reference is made to the contact of the Demon's Bluff Formation with the Boonah Sandstone on p. 113. At the only clear exposure of the contact of the Demon's Bluff and the Jan Juc Formations at Addiscot near Bell's Headland (Section 5) it is gradational. It is impossible to be quite sure of the stratigraphic position of the sediments and volcanic rocks at the top of the Formation at Anglesea, and of the volcanic rocks between Airey's Inlet and Urquhart's Bluff, relative to the passage beds at Addiscot. The presence of coarse sands in erosion hollows in the agglomerate and of volcanic breccia interbedded with the Demon's Bluff sediments indicates that the agglomerate should be referred to the Demon's Bluff Formation, so that at Airy's Inlet there were apparently some minor vertical movements immediately prior to the deposition of the overlying limestones; however, there is certainly nothing more than erosional disconformity between the Demon's Bluff Formation and the overlying limestones at this locality.

The Demon's Bluff Formation is sub-divided as under:

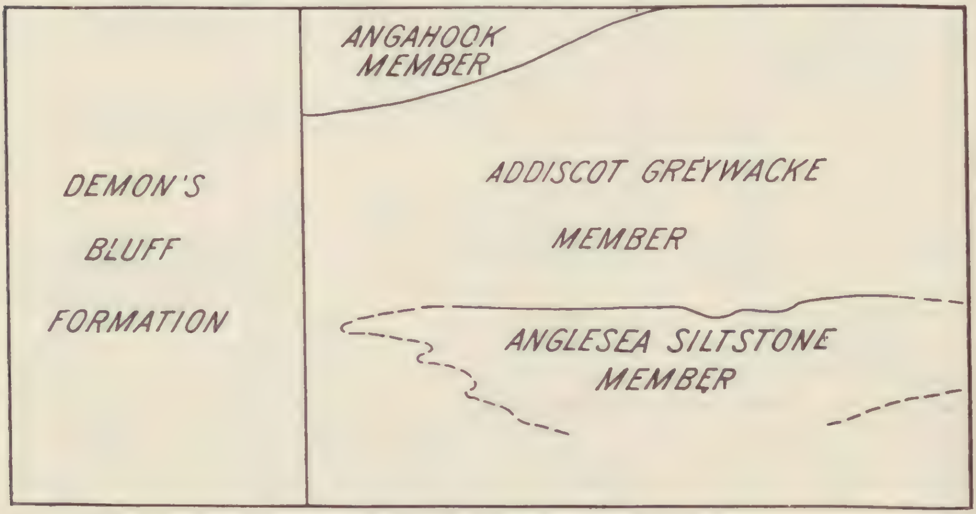


FIG. 5.—Subdivision of Demon's Bluff Formation.

ANGLESEA SILTSTONE MEMBER. This member of the Demon's Bluff Formation is defined as the brownish black *Cyclammina*-bearing siltstone between the top of the Boonah Sandstone and the pale red-purple greywacke (Addiscot Member) of

the Demon's Bluff cliffs, the cliffs near the Black Rocks, Point Addis, Jarosite Headland and Addiscot. These are the beds which form the lower part of the cliffs at Demon's Bluff to which Singleton (1941, p. 25) in a strict lithological sense, originally applied the name "Anglesean".

Some details concerning the Anglesea Member are given in—

Section	Samples	Thickness ft.
1	E.1 to E.6	48+
2	W.1 to W.3	19+
Jarosite Headland	—	35+
5	B.106	37+

and in the palaeontological notes on those sections.

The Anglesea Member has a remarkably homogeneous lithology. It is a siltstone, arkosic in places, coloured brownish black and characterized everywhere by filled worm burrows and algal (?) remains (Glover, 1954; Dallwitz, 1954). Reference is made to its characteristic lithology and jointing on pp. 84 and 90.

No section is known which reveals the base of the Anglesea Member and the bore logs are not sufficiently detailed to give any information about the contact.

The contact between the Anglesea and Addiscot Members is well exposed in several places and reference has been made thereto on pp. 84, 85 and 92. In some places the passage is gradational; in others there is disconformity between the two. This disconformity was due to minor local movements; the sediments below and above it differ little in lithology and the ecological conditions were unchanged. Slight as are the measurable differences between them, the members show out in striking contrast on weathering—the joint surfaces in the Anglesea Member commonly do not pass into the Addiscot Member; bedding planes are difficult to identify in the Anglesea Member but show out clearly in the Addiscot Member. The Anglesea Member is regarded as a carbonaceous (lignitic) lens in the Demon's Bluff Formation. Its westerly limit is somewhere between Anglesea and Mogg's Creek, but its eastern and other limits are not known. It extends east at least as far as Bird Rock; the sample in the Mines Department from a depth of 640 ft. in No. 3 Jan Juc bore is typical of the member. (See Plate IV, fig. 3; Plate V, fig. 1.)

ADDISCOT (GREYWACKE) MEMBER. This Member in the type cliff section at the eastern end of Addiscot Beach includes all the beds between the top of the Anglesea Member and the Jan Juc Formation. On the west side of Anglesea River and between Urquhart's Bluff and Airey's Inlet, volcanic rocks and sediments (Angahook Member) occur between the top of the Addiscot Member and the Jan Juc Formation. The type section is No. 5, from the erosion surface above sample B.106 to B.110 inclusive; thickness 64 ft.

A complete section is exposed also on the west side of the Anglesea River—Section 3—from the erosion surface below W.4 to W.11 inclusive; thickness 73 ft.

Partial sections are exposed between Anglesea River and Addiscot. See Section 1 (56 ft.); Section 4 (40+ ft.), and general notes on pp. 90 and 92.

Except for a lightening in colour towards the top the Addiscot Member is as remarkably homogeneous as the Anglesea Member. In fact it resembles this Member closely in everything but colour; it is slightly coarser in grain than the Anglesea Member and hence has been designated greywacke rather than siltstone. A petrological description is given by W. B. Dallwitz (1954).

The section at Addiscot shows gradual passage from the Addiscot Member to the Jan Juc Formation. Between Anglesea and Airey's Inlet, however, there was apparently a change from marine to fluviatile conditions which coincided with volcanic activity. After the volcanic episode there was some erosion and deposition of coarse sands before the overlying limestones (Point Addis Member) were deposited.

ANGAHOOK MEMBER. This Member is named after the Parish of Angahook in which the best section occurs—Section 3 above the top of W.11 (see also Plate IV, fig. 2).

At the type locality the Angahook Member is 70 ft. thick. The lower half consists of alternations of shale with volcanic breccia and agglomerate; the upper half consists predominantly of poorly bedded claystone and fine sandstone. The bottom bed of the Member is a thin seam of brown coal and most of the lower half consists of sediments deposited in fresh water, but the presence of coprolites associated with pebbles of basalt about the middle of the Member shows reversion to marine conditions. For details see Section 3.)

At Airey's Inlet the Angahook Member is represented by about 50 ft. of volcanic rocks, dominantly coarse agglomerate, overlain disconformably by calcarenites of the Point Addis Member. In one place—$\frac{1}{4}$ mile north of Eagle Rock—twelve feet of well-bedded coarse quartz sandstone occurs between the agglomerate and the calcarenite. (For details see pp. 104 and 105.)

The Angahook Member is represented at Point Addis by about 50 (43) ft. of unfossiliferous sediments (between PA.1 and PA.6 of Section 4). Though poorly exposed these sediments are like those in the type section except that they apparently do not include volcanic rocks. At Point Addis the upper disconformable contact of the Angahook Member with the Point Addis Member closely resembles the section at Airey's Inlet.

West of Airey's Inlet the Angahook Member consists of the unfossiliferous coarse sandstone and clays exposed at the bridge over Airey's River (Painkalac Creek) and similar beds in Section 24. Volcanic clay (ashstone) occurs interbedded with the sandstone in Section 24.

The Member cannot be identified at the eastern end of Addiscot Beach where there is an almost continuous section from the upper beds of the Demon's Bluff Formation to the Jan Juc Formation. Somewhat arbitrarily it may be said that it is represented in this Section by B.110—6 ft. of unfossiliferous brown and yellow sandstone—but it is more probable that deposition of marine sediments was taking place continuously at Addiscot while freshwater sediments were being deposited elsewhere.

Details of the sections exposed in the cliffs eastward from Split Point are given on pp. 104, 105. Reference is made to the Urquhart's Bluff agglomerate and the overlying clays on p. 104, where also correlation with the upper part of Section 3 at Anglesea is discussed. Details of the Angahook Member as exposed west of Anglesea River are included in Section 3, samples W.12 to W.102 inclusive, thickness 69+ ft.

The lower contact of the Member is not seen at Split Point. West of Anglesea this contact is marked by a sharp change in lithology corresponding with a change from the marine conditions in which *Cyclammina* flourished to freshwater conditions. The upper contact is described on pp. 88 and 89.

MICROPALAEONTOLOGY OF DEMON'S BLUFF FORMATION. The most striking feature of the microfaunal assemblage in the lignitic silts and greywackes of the Demon's Bluff Formation is the uniformity of genera and species of foraminifera, which in

turn indicates uniformity of bathymetric and climatic conditions at the time of deposition. The foraminiferal assemblage consists of the arenaceous genera *Ammodiscus, Bathysiphon* and *Cyclammina*. Small fragments of bryozoa and valves of thin-shelled ostracoda are rarely present. *Cyclammina* dominates the assemblage and in many of the samples examined it is present to the exclusion of all other forms. *Ammodiscus, Bathysiphon* and *Cyclammina* are benthonic foraminifera, and recent investigations indicate that these forms thrive in stagnant, marine waters as well as in deep water. According to Lowman (1949) the assemblage *Cyclammina-Bathysiphon* is found in some deposits in which the mineral and plant components suggests a low oxygen content. He states further that these two arenaceous genera together with certain other benthonic forms will "tolerate conditions that normal assemblages do not tolerate".

It seems, therefore, that the Demon's Bluff Formation was laid down in almost stagnant water in which plant remains were common and into which tides floated such neritic forms as *Dorothia* and *Cibicides* as well as bryozoa and ostracoda.

The foraminifera recognized in the Formation are as follows:

Ammodiscus incertus (d'Orb.) var. *macilenta* Chapman
Ammodiscus cf. *parri* Crespin
Bathysiphon angleseaensis Crespin
Cibicides cf. *umbonifer* Parr
Cyclammina incisa Stache (abundant)
Cyclammina paupera Chapman (common)
Cyclammina rotundata Chapman and Crespin (common)
Cyclammina sp. (small species and very common)
Dorothia cf. *parri* Cushman
Lituola simplex Chapman
Rhabdammina sp.

Cyclammina is very abundant in the purplish greywacke which forms the upper part of the Demon's Bluff Formation (Addiscot Member) in the vicinity of Demon's Bluff, east of Anglesea, which Singleton (1941) regarded as unfossiliferous. The tests, some of which have a diameter of 4 to 5 mm., are better preserved in these beds than in the underlying lignitic siltstone (Anglesea Member). However, the greatest number of individual tests in any one sample came from Sample E.2 in Section 1, near the top of the Anglesea Member, in which 64 complete tests were counted.

Cyclammina is represented by three species, *C. incisa, C. paupera* and *C. rotundata*. *C. incisa* (Plate VII, fig. 3) was described by Stache (1864) from beds in New Zealand now regarded as Lower Oligocene, and it has been recorded from the Upper Eocene in the Perth bores, Western Australia. *C. paupera* (Plate VII, fig. 4) was described by Chapman (1904) from beds at Brown's Creek, 50 miles south-west of Anglesea, which lithologically closely resemble the Demon's Bluff Formation and are similar in age. However, another species, *C. complanata*, also described by Chapman, from Brown's Creek, has not been found in the Torquay-Anglesea area. *C. rotundata* (Plate VII, figs. 5a, 5b) was described by Chapman and Crespin ((1930b) from marls of "Janjukian" age at the depth of 1,295 ft. in No. 1 Bore, Parish of Bumberrah Metung), Gippsland.

The rich *Cyclammina*-bearing beds of the Anglesea area are known to extend westward to south-eastern South Australia and eastward to Gippsland in south-eastern Victoria. This type of deposit, which boring has shown to be of considerable thickness, seems to be confined to the Tertiary of south-eastern Australia.

Ammodiscus is moderately common in the siltstones of the Demon's Bluff Formation but the tests are usually fragmentary. *Ammodiscus incertus* var. *macilenta* is recorded; this variety was described by Chapman (1904) from Brown's Creek. Fragments of large tests are referred to *A. parri* (Plate VII, fig. 2) described by Crespin (1950). One complete but poorly preserved test from the cliffs immediately west of The Black Rocks measures 4 mm. in diameter. A large species most probably referable to this form is fairly common in beds of Janjukian age in bores in Gippsland.

Bathysiphon anglesceaensis (Plate VII, fig. 1) was described by Crespin (1950) from sample E.8 which came from 5-10 ft. above the base of the Addiscot Member at Demon's Bluff (Section 1). The species is fairly common in samples from the Demon's Bluff cliff.

Both large and small tests of the genus *Dorothia* are present fairly generally. The larger ones are referred to *D. parri* Cushman. The smaller ones, though common, are too poorly preserved for specific determination.

The only calcareous genus noted is a small *Cibicides* which is similar to a species *C. umbonifer* described by Parr (1938) from beds in the King's Park bore, Perth, Western Australia, which he referred to the Upper Eocene.

Torquay Group

This Group is defined as including all the beds between the top of the Demon's Bluff Formation and the top of the limestone which forms the cliffs between Bird Rock and the mouth of Spring Creek (Zeally Limestone Member). Torquay is the name of the largest village in the area described which is commonly referred to as the Torquay district. No single lithological term describes the group adequately. Two formations may be recognized, the plane of division being at the top of marker "F" in Section 7 (Bird Rock Bluff).

From the Bird Rock Bluff to the locality FD., about midway between Fisherman's Steps and Dead Man's Gully, the lower formation is a shelly friable calcarenite with poorly defined stratification. Shelly fossils are present in abundance and glauconite pipes are common. Westerly from locality FD., massive non- or poorly-fossiliferous calcilutite beds from 1 to 3 ft. in thickness occur. Gradually, however, as traced westerly to Bell's Headland almost the whole of the exposed portion of the Formation is composed of a tough calcarenite (Point Addis Limestone Member), lithologically like the Zeally Limestone Member, with which it has been, incorrectly, correlated. Judging by exposures immediately west of Bell's Headland and the records of bores near Bird Rock, the lower portion of the Formation is sandy and shelly between these points. Between Bell's Headland and Point Addis the lower sandy, shelly beds die out and the Point Addis Member is in contact with the Demon's Bluff Formation. At Airey's Inlet all the post-Demon's Bluff beds exposed are limestone (calcarenite)—tentatively included in the Point Addis Member.

The upper formation maintains a fairly uniform lithology westerly from Bird Rock Point. It consists of marl passing up into siltstone, has well-defined stratification and contains some thin but distinct marker beds of silty limestone (calcilutite). Easterly from Bird Rock Point the Formation shows a marked and abrupt change to the dominantly calcarenitic Zeally Limestone Member. Compared with the lower Formation it has a sparse mega-fauna.

Details of the lithology of the Group are given in the description of Sections 4-19 inclusive and in Fig. 7. The greatest thickness of the Group—216 ft.—is exposed in cliff sections from a point about midway between Fisherman's Steps

and Bird Rock (Section 9) to Torquay (Section 18). However, the base is not exposed in this area. The bore reported upon by Chapman (1922a) proved an additional 70 ft. of sandy, shelly glauconitic marls below the natural exposures (Section 9) and it is estimated that about another 50 ft. was proved by the Jan Juc Nos. 1-5 bores (D.M.V. 1938) giving a total thickness of about 340 (336) ft. The 50 ft. estimate is based on the following argument. Jan Juc No. 4 bore was well placed to prove the Tertiary sequence (and, incidentally, to test the oil possibilities of the anticlinal structure between Bird Rock and Fisherman's Steps). It was put down at a point—elevation 114 ft. above sea-level—almost vertically above the 70 ft. bore (Chapman 1922a; Section 9) and passed through flat-lying beds at the crest of a symmetrical anticline; bore thicknesses are therefore true thicknesses. The driller's log is not much use for stratigraphical purposes. The bore could not have reached the Demon's Bluff Formation above 211 ft.—114 plus 97 (Section 9)—but 32 ft. of "sandy ligneous clay" is logged at 106 ft.; possibly this represents the grey marl (Marker "G") in the Bird Rock Section (Section 7). By drawing correlation lines between bores No. 3 and 4 and using the information available concerning No. 3 bore (see p. 114) it seems reasonably certain that the bottom of the 70 ft. bore was within 125 ft. or less of the top of the Demon's Bluff Formation (see Fig. 4). Inspection of the logs of the bores themselves suggests that the bottom of the 70 ft. bore was possibly about 50 ft. from the top of the Demon's Bluff Formation. However, this is only an informed guess. This correlation incidentally shows that the core from a depth of 170 ft. in No. 3 bore examined by Chapman and Singleton (1925) came from about the top of the lower shelly part of the Group and was therefore stratigraphically higher (not lower, as Chapman and Singleton thought) than the beds proved by the 70 ft. bore (see pp. 82 and 114, and Fig. 4).

At Bell's Headland (Section 5), Point Addis (Section 4) and Airey's Inlet (Section 19) the base of the Group is exposed and the thicknesses are respectively 159, 92 and 75 ft. At these localities, however, it is impossible to determine how much of the upper beds has been removed by erosion.

The relationship of the Torquay Group to the Demon's Bluff Formation is described on p. 116; its relationship to the next succeeding formations is not revealed by any section in the area described in this paper but some deductions can be made concerning it on palaeontological evidence (see p. 125).

The Torquay Group is subdivided as illustrated in Fig. 6.

Jan Juc Formation

The Jan Juc Formation is defined as that part of the Torquay Group below the top of marker "F" in Section 7 at Bird Rock Point. At the type locality (Sections 7 and 9) the exposed section of the Formation consists of 57 ft. of friable calcarenite with a great abundance of shelly fossils and a considerable amount of glauconite. (See Glover, 1954, for notes on glauconite.) By reference to Sections 7-11 in Fig. 7 and the discussion above it is apparent that the known thickness of the Formation at the type locality, including the beds proved by the 70 ft. bore (Section 10), is 129 ft., and that its probable total thickness is about 180 ft.

Bird Rock Point is regarded as the type locality because it is the best known. The most complete section, however, is exposed on the western side of Bell's Headland and in the low cliffs at the eastern end of Addiscot Beach.

The Formation is not exposed east of Bird Rock; south-westerly from Bird Rock its upper part is continuously exposed for two miles. As noted on page 120 from locality FD. westerly a facies change is apparent.

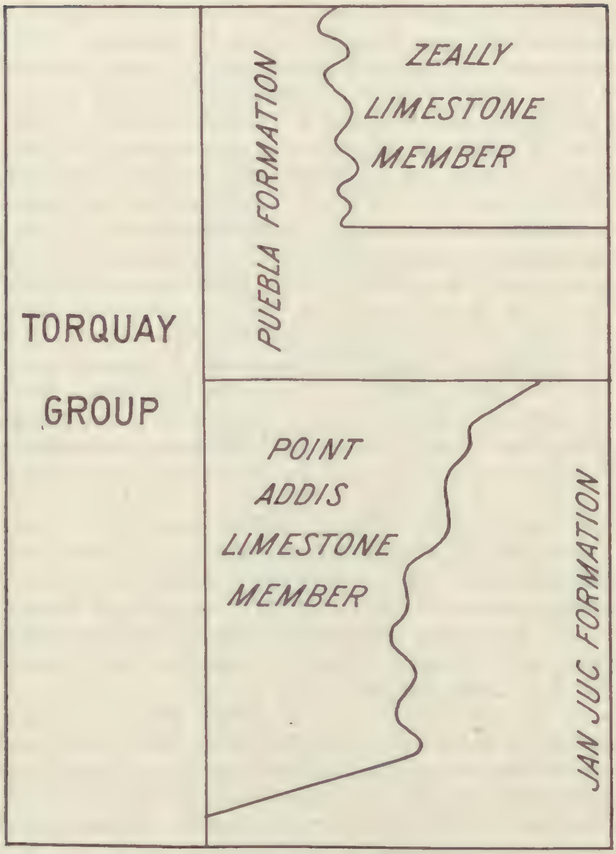


Fig. 6.—Subdivision of Torquay Group.

The top of the Jan Juc Formation at Bird Rock is a well-cemented calcilutite (Marker "F") from a few inches to 2 ft. in thickness, lenticular in places but almost continuous to a point about midway between Fisherman's Steps and Dead Man's Gully. From that point westerly, although the boundary between the Formation and the overlying beds is distinct, this particular marker loses its identity. Another well-marked similar bed "E" forms the top of the small stack known as Bird Rock. This marker dies out a few hundred feet east of Dead Man's Gully. The lower part of the beds exposed at Bird Rock and Fisherman's Steps is characterized by a great abundance of the pelecypod *Glycymeris ornithopetra* Chapman and Singleton. One bed ("D"), composed largely of these shells, although only about 9 in. thick, forms a persistent horizon marker from Bird Rock to locality FD. (Section 12). *Glycymeris* is common west of this locality but the marker "D" peters out about 100 ft. east of Dead Man's Gully. This part of the section passes below sea-level 100 ft. west of Dead Man's Gully and where it is exposed farther west at Bell's Headland it is in limestone facies and *Glycymeris* is not present. The lower sandy beds at Bell's Headland contain very large numbers of gastropods.

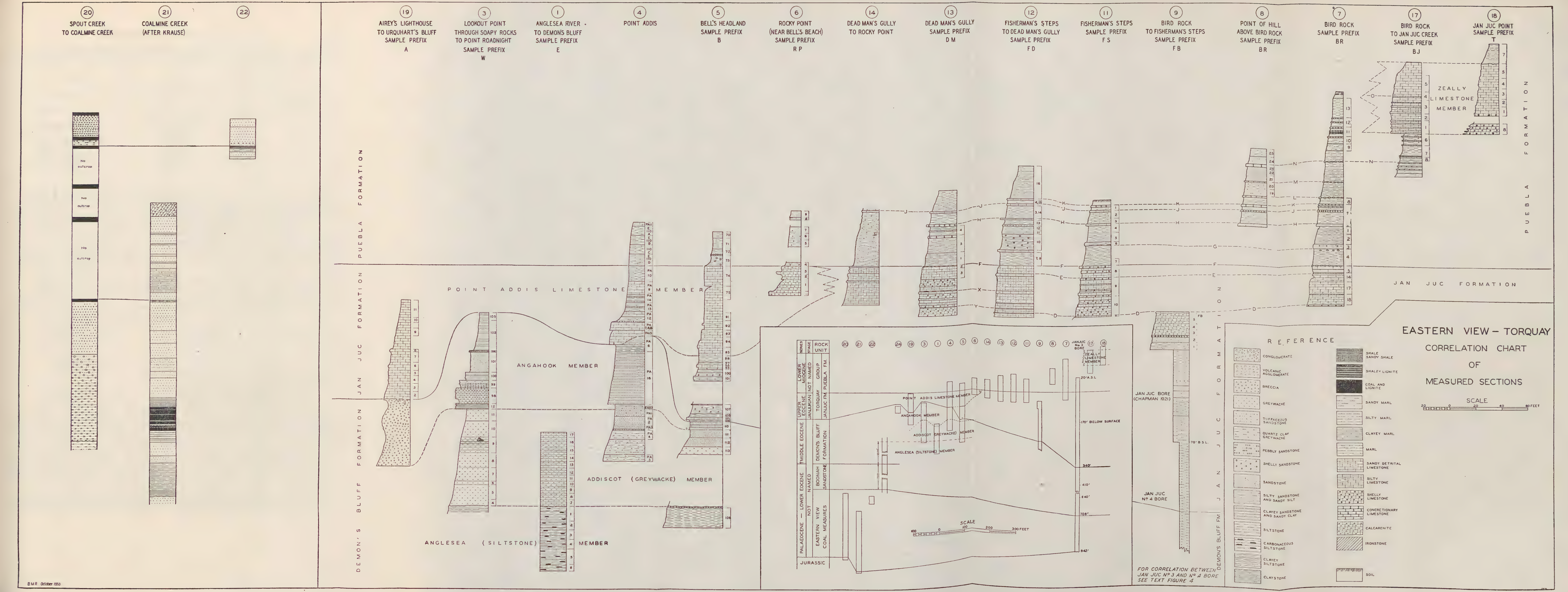


Fig. 7.—Eastern View - Torquay; Correlation Chart of measured Sections.

1

Details of the formation and additional notes on the changes in its lithology are given in earlier pages and may be identified from east to west as under:

Sections	Samples	Thickness ft.	in.
7 Bird Rock	BR.5 down to BR.18	29	6 (Exposed
		180	(Estimated)
9 and 10	FB.1-5 (27 ft. 5 in.) plus 70 ft. bore	97+	
11 Fisherman's Steps	FS.8-11	39+	
12	Below FD.1	38+	
13 Dead Man's Gully	Below DM.1	36+	
6 Rocky Point	RP.1-3	22+	
5 Bell's Headland	B.74-B.109	112	
4 Point Addis	PA.10-PA.15	60	
19 Airey's Inlet	A.2-A.11	75+	

The facies change are summarized in Fig. 7.

The contact of the formation with the overlying beds has been described above; it is sharp but concordant and evidently marks a significant change in conditions of sedimentation expressed by change in lithology, reduction in shelly fossil content, and reduction in the development of glauconite. (See Plates V and VI.)

There is a great deal still to be discovered about the origin of glauconite but it seems agreed that it is a product of diagenesis* and an index of slow, even negative, sedimentation (Hadding, 1932; Shephard, 1948; Twenhofel, 1932), an inference supported by the presence of at least one wave cut platform in the Jan Juc Formation.

The contact with the Demon's Bluff Formation is discussed on pp. 92 and 116.

Pritchard (1925, p. 155) suggested that seven sets of beds characterized by certain mega-fossils could be recognized in what is defined in the present paper as the Torquay Group. By reference to Singleton's comments (1941, p. 39) they may be approximately identified as follows:

Scutellina limestone	Zeally Member at Jan Juc Point.
Cellopora limestone	Zeally Member between Jan Juc Creek and Bird Rock.
Ancilla Clays and Septarian Limestones	Puebla Formation in type section at Bird Rock.
Chione Clays	Top of Jan Juc Formation at Bird Rock Bluff between markers "E" and "F".
Glycymeris beds and *Limopsis* beds	Jan Juc Formation below marker "E".

Point Addis Limestone Member. The limestone facies of the Jan Juc Formation is designated the Point Addis Limestone Member and the type section is provided by the interval PA.15/PA.10 in Section 4 at Point Addis. The name "Addis Limestone" was first used—informally—for this Member by Hall (1910, p. 45). The word "Point" has been retained in the name so that it will not be confused with "Addiscot". A generalized description of the Member has been given in discussing the Torquay Group and the Jan Juc Formation and details are given in the description of the measured sections from west to east as under:

*The larger masses of glauconite in the Jan Juc Formation obviously were formed in place. Some are parallel to the bedding, others are in the form of vertical pipes. Those parallel to the bedding are irregular in shape and could not have survived transportation.

Sections	Samples	Thickness (ft.)
19 Airey's Inlet	A.2-A.11	75+
4 Point Addis	PA.10-PA.15	60
5 Bell's Headland	B.74-B.94	62
6 Rocky Point	Below RP.4	22+

From these descriptions it will be noted that at Airey's Inlet and Point Addis the Member appears to represent the same stratigraphical interval as the Jan Juc Formation, but at Bell's Headland it represents only the upper part of that interval—60 ft. of sandy beds with a gastropod fauna occur between the base of the Member and the top of the Demon's Bluff Formation. Between Rocky Point and the locality of Section 14 the Member loses its identity; it passes into a number of thin beds of calcilutite interfingering with the loosely cemented shelly facies of the Jan Juc Formation.

The upper surface of the Member is not exposed at Airey's Inlet, but at all places where it is exposed it is in sharp contact with the Puebla Formation. The lower contact at Airey's Inlet is with agglomerate or coarse sand of the Angahook Member; at Point Addis with gritty clays of the same Member; at Bell's Headland with the sandy gastropod-bearing beds referred to above. The base is not exposed at Rocky Point.

Puebla Formation

The Puebla Formation is defined as that part of the Torquay Group above the top of the Jan Juc Formation.

Puebla is the old name for the village of Torquay and is the name of the parish north-east of the lower part of Spring Creek. A name more closely associated with the type locality would have been preferred, but such names are few and either unsuitable or pre-empted.

The type section is exposed at the Bird Rock Bluff and between the Bluff and the mouth of Jan Juc Creek—Section 7 above the top of Marker "F" and Section 17. At the type locality the Formation consists of marl and siltstone with six massive to concretionary beds of calcilutite each up to 2 ft. thick. East of the Bird Rock Bluff the upper part of the Formation changes sharply to calcarenite (Zeally Limestone Member).

The thickness of the Puebla Formation at the type locality is about 160 (158) ft. Details of the lithology are given in Sections 7 and 17 but notes on the outcrop of some of the more distinctive beds are given here in ascending sequence.

The lowest 10-15 ft. of the Formation are more clayey than most of the higher beds. Almost everywhere they have slumped, and clean outcrops are rare and transient. The next succeeding bed (e.g. FS.16) though not obviously different from those above it, makes a characteristic smoothly rounded outcrop convex outwards from the cliffs.

The foregoing is true of the sections between Bird Rock and locality RP.; west from there the lower beds are like the remainder of the Formation.

The calcilutite markers "H", "J" and "K", though generally similar, have individual characteristics. "H" is light olive grey in colour (5 Y 5/2) and is the most massive of the three. Because of this it stands out best; the soft beds below it slump away forming an inverted ledge. "J" is yellow, pitted and lenticular. "K" is grey, mottled yellowish brown; it is continuous but has a concretionary structure and roughly cubical jointing.

Westerly from Bird Rock only partial sections are exposed. They show lithological similarity with the type sections and many individual beds can be traced from place to place. At Fisherman's Steps the thickness exposed is 50 ft. The markers "H", "J" and "K" at the top of the section can be traced continuously from Bird Rock to Fisherman's Steps. At locality FD., 69 ft. of the Formation are exposed including the same three markers. The lithology of the beds at FD. is somewhat different from those east and west of it; they are darker in colour and at outcrop contain much gypsum. This change is also expressed in the microfauna. At Dead Man's Gully the section is 57 ft. thick and includes markers "H" and "J"; "K" dies out on the western side of FD.; "H" dies out west of Dead Man's Gully; "J" can be traced to a point 1,200 ft. west of Dead Man's Gully. Westerly from this point to Rocky Point the cliffs decrease in height and outcrops of the Formation are obscured by dense scrub. The partial sections exposed at Rocky Point, Bell's Headland and Point Addis consist chiefly of silty marls with white calcareous nodules but no other distinctive features. The thickness at these localities is 42, 26 and 33 ft. respectively.

No exposures of the Puebla Formation are known west of Point Addis.

The contact of the Puebla Formation with the Jan Juc Formation has been described. Its contact with the next succeeding Tertiary beds is not exposed in the area examined.

Zeally Limestone Member. The limestone (calcarenite) which forms the cliffs between Bird Rock and the mouth of Spring Creek are named the Zeally Limestone Member of the Puebla Formation. Specifically it is defined as Section 17 above the base of BJ.1 which is the same stratigraphical interval as Section 18, T.8/T.5. The thickness of both these sections is 54 ft. Calcarenites and clayey marls which form the low cliffs at Point Danger are also part of this Member though detailed correlation with the type section is not possible.

Details of the lithology are given in the description of Sections 17 and 18 and relationship to adjacent formations is discussed in pp. 100-102.

Zeally is the name of the Bay immediately north of Point Danger; Point Danger itself is named Zealey Point on the Admiralty charts. No other suitable name is available along the short strip of coast where the Member crops out.

Micropalaeontology of the Torquay Group

Foraminifera are present in different degrees of abundance in the rocks comprising the Torquay Group. They are abundant in the beds of the Jan Juc Formation but less common in those of the Puebla Formation.

A distribution chart of species found in the Torquay Bore (Chapman, 1921) in the FB. section (between Fisherman's Steps and Bird Rock) in the BR. section (Bird Rock) and eastward to Section T. (headland south of the mouth of Spring Creek), is given in Table XVI, and it illustrates the striking change in the foraminiferal assemblages of the Janjukian (Upper Eocene) and the Balcombian (Lower Miocene). In this chart the age of the described species is indicated by symbols.

Jan Juc Formation. The only natural section where the Jan Juc Formation is seen in contact with underlying Demon's Bluff Formation is the cliffs at the back of the eastern end of Addiscot Beach (Section 5); here the faunal change is as marked as the lithological one. Numerous tests of *Cyclammina*, the characteristic form of the Demon's Bluff Formation, are present in all samples up to and including B.111 and although *Cyclammina* occurs sporadically throughout the Jan Juc Formation it is not present in the beds immediately overlying B.111; in samples B.105

and B.109, six feet above B.111, typical foraminifera of the Jan Juc Formation, such as *Massilina torquayensis*, are present.

In the type section, the upper lithological boundary* of the Jan Juc Formation coincides with the microfaunal one which is based on the last appearance of one of the ten species listed below. West of Dead Man's Gully, the foraminiferal assemblages are clearly governed by facies changes; the lithology of the beds changes from loosely compacted argillaceous calcarenite at Bird Rock, Fisherman's Steps and Dead Man's Gully to well-cemented calcarenite at Rocky Point, Bell's Headland and Point Addis (Point Addis Member).

Foraminifera are abundant in most of the rock samples from the Jan Juc Formation and the assemblage is dominated by a small group of species which are restricted to the Formation (Crespin, 1950b). These species are:

Bulimina pupula Stache
Dimorphina janjukensis Crespin
Frondicularia victoriae Crespin
Hantkenina alabamensis Cushman, subsp., *compressa* Parr
Massilina torquayensis (Chapman)
Quinqueloculina ornithopetra Crespin
Quinqueloculina singletoni Crespin
†*Sherbornina atkinsoni* Chapman
Vaginulinopsis gippslandicus (Chapman and Crespin)
Victoriella plecte (Chapman)

Another characteristic species, *Lamarckina glencoensis* Chapman and Crespin, is found also in the lower part of the Puebla Formation.

In a westerly direction from Bird Rock Cliff, the type locality for the Jan Juc Formation, to Point Addis (Point Addis Limestone Member), the lithology becomes more calcareous. Some of the characteristic species listed above disappear but *Victoriella plecte* persists. *Sherbornina atkinsoni* is also commonly present, but at Point Addis it seems to be replaced by a genus with affinities to the Middle Eocene genus *Eoannularia*‡ of Cole and Bermudez (1944) and with the genus *Annulopatellina* of Parr and Collins (1930). This form is also present in the Upper Eocene beds at Johanna River. *Hantkenina alabamensis* subsp. *compressa* is restricted to a very narrow band at the top of the Jan Juc Formation in the Bird Rock section (Crespin, 1952).

Glaessner (1951) shows *Hantkenina alabamensis*, *Victoriella plecte* and (doubtfully) *Sherbornina* as occurring in and characteristic of three separate zones in the Victorian Tertiary sequence. As indicated above and as stated by the authors in earlier notes (Crespin, 1952a; Raggatt, 1952) *Hantkenina* and *Victoriella* occur together at Brown's Creek and Bird Rock. *Sherbonina* is commonly associated with *Victoriella* at Bird Rock.

A distribution chart of selected foraminifera from Bell's Headland and Bird Rock cliff is shown in Fig. 8.

Associated with the above species are numerous small species, several of which persist throughout the Formation. Some of these were described by Parr from

*See comment, p. 137.

†Professor A. Wood (oral communication) considers the genus *Sherbornina* of Chapman to be a *Cycloloculina*, a genus which is characteristic of the Eocene in Europe.

‡Since this paper was read, Miss M. Wade (1955) has given this form the new generic name of *Crespinina*. It was described from Eocene deposits at Kingscote, Kangaroo Island, South Australia.

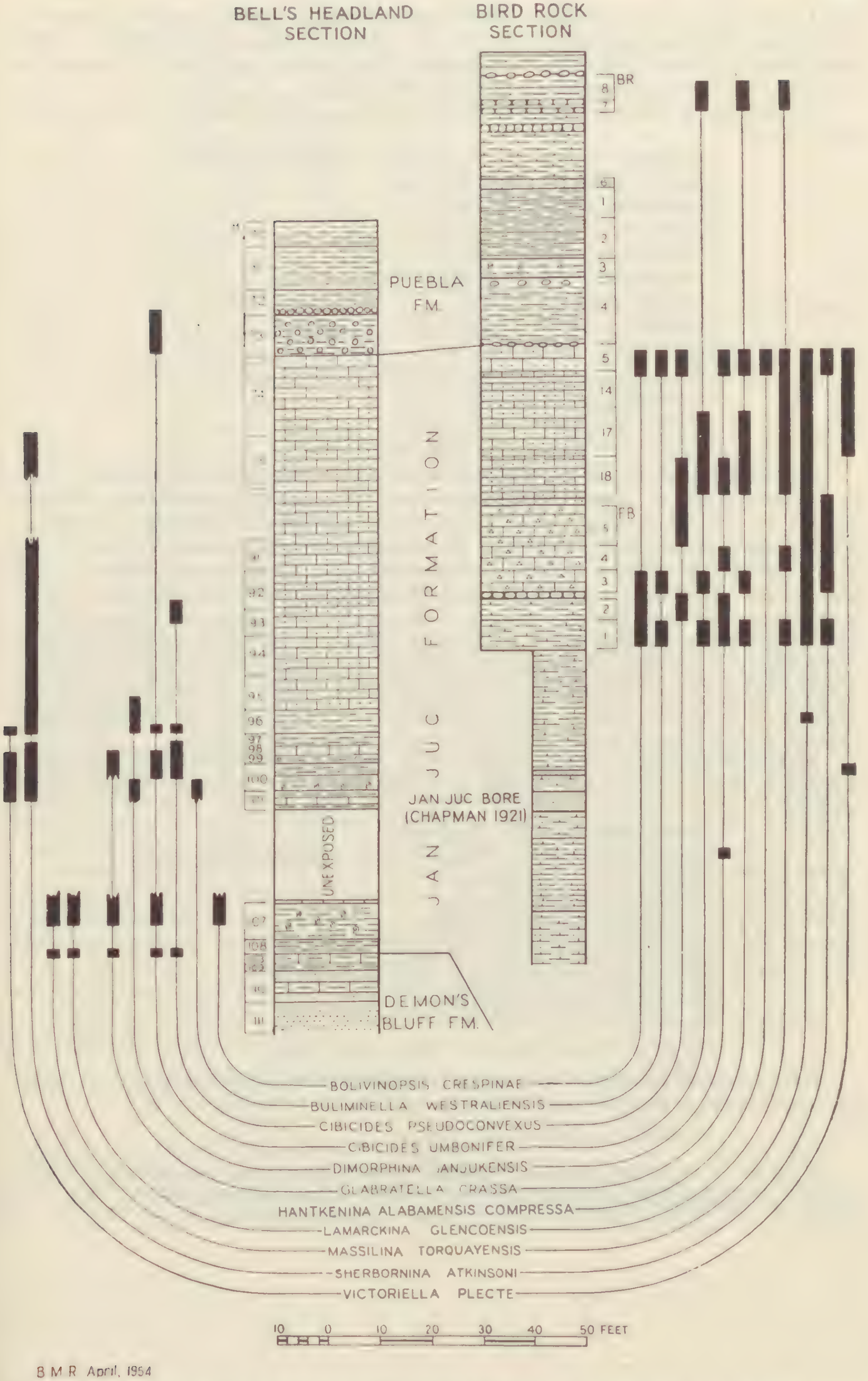


FIG. 8.—Distribution Chart of selected foraminifera from Bell's Headland and Bird Rock Cliff.

the Upper Eocene of the King's Park Bore, Perth, Western Australia, some by Finlay and Dorreen from the Upper Eocene of New Zealand, and some by Cushman, Bandy, Howe, Nuttall and others from the Eocene and Lower Oligocene of America and Europe. Several new species are present.

The following species were described by Parr (1938) from the King's Park Bore, Perth:

Alabamina obtusa (B. & H.) var. *westraliensis* Parr
Angulogerina subangularis Parr
Anomalina perthensis Parr
Anomalina westraliensis Parr
Bolivinopsis crespinae Parr
Ceratobulimina westraliensis Parr
Cibicides umbonifer Parr
Cibicides pseudoconvexus Parr
Globorotalia chapmani Parr
Guembelina venezuelana Nuttall var. *rugosa* Parr
Heronallenia pusilla Parr
Lagena perthensis Parr
Pseudoglandulina clarkei Parr

Despite the evidence of the above species and the association at Johanna River of *Victoriella plecte*, *Lamarckina glencoensis*,* *Dimorphina janjukensis*, *Frondicularia victoriae* and *Vaginulinopsis gippslandicus* with *Hantkenina*, Glaessner (1953) casts doubt on the record of *H. alabamensis* subsp. *compressa* in the top of the Jan Juc Formation at Bird Rock, on the grounds of faunal differences and absence of "other restricted species usually associated with" *Hantkenina*. A close comparison has been made of species found with *Hantkenina* at Johanna River and Brown's Creek with those in sample BR.5 and below at Bird Rock. The resemblance is striking. Amongst these forms are several undescribed species of *Angulogerina* and a new species of *Cibicides* which occurs not only in the Eocene deposits at Christie's Beach, Port Noarlunga, and Maslin Beach, Aldinga, South Australia, but also in south-western Victoria and at Bird Rock.

Species described by Finlay (1939, 1947) and Dorreen (1948) from the Upper Eocene of New Zealand and present in sediments of the Jan Juc Formation are as follows:

Asterigerina cyclops (Dorreen)
Cibicides perforatus (Karrer) var. *notocenicus* Dorreen
Cibicides vortex Dorreen
Glabratella crassa Dorreen
Globigerinoides index Finlay
Gyroidina scrobriculata Finlay
Planorbulina macphersoni Finlay
Rotorbinella finlayi Dorreen
Sigmoidella bortonica Finlay
Sigmomorphina haeusleri Parr and Collins

American and European species described from the Eocene and Lower Oligocene and found in the Jan Juc Formation include the following:

Cassidulina alabamensis Bandy

*The species of *Lamarckina* which occurs at Johanna River is *L. novozealandica* Dorreen not *L. glencoensis* Chapman and Crespin as determined by I.C. However, further study of the specimens from Bird Rock shows that both species are present there.

Cassidulina armosa Bandy
Cibicides perlucida Nuttall
Cornuspira byramensis Cushman
Dentalina jacksonensis (Cushman and Applin)
Discorbis assulatus Cushman
Dorothia subglabra (Gümbel)
Epistomina eocenica Cushman and Hanna
Glabratella petalifera (Howe)
Globigerina eocenica Terquem
Globigerina mexicana Cushman
Globigerina ouatchitensis Howe
Guembelina multicellaris Hussey
Gyroidina soldanii (D'Orb) var. *octocamerata* Cushman and Hanna
Hantkenina alabamensis Cushman
Heronallenia vicksburgensis Cushman
Lagena mississippiensis Cushman and Todd
Lagena scarenensis Hantken var. *glabrata* Selli
Nonionella hantkeni (Cushman and Applin)
Robertina ovigera (Terquem)
Robertina wilcoxensis Cushman and Ponton
Robulus alabamensis Cushman
Sigmoidella plummerae Cushman and Ozawa
Stomatorbina torrei (Cushman and Bermudez)
Tubulogenerina vicksburgensis Cushman
Virgulina dibollensis Cushman and Applin

Globigerina pseudobulloides and *G. triloculinoides*, which occur in many samples, were described by Mrs. Plummer (1926) from the Midway (Palaeocene to Lower Eocene) of Texas. Many new species are present and many other specimens show close relationships with species described from the Eocene outside Australia.

Associated with the species listed above, and especially with the eleven characteristic species, are certain species described from the Miocene beds of Australia (Heron-Allen and Earland, 1924; Chapman, 1910; Chapman, Parr and Collins, 1934; Cushman, 1936). Cushman (1933) in describing new species from the Lower Oligocene of Mississippi, remarked that "they show a very close relationship to the foraminifera of the Indo-Pacific, particularly to that of the Miocene of Australia". Included in this comment are *Angulogerina vicksburgensis* which is indistinguishable from *A. australe* (*Uvigerina canariensis* var. *australe*) (Heron-Allen and Earland, 1924) and *Heronallenia vicksburgensis* which is closely related to *H. wilsoni* described by Heron-Allen and Earland (1922) from Recent seas but which is characteristic of Miocene assemblages in Australia.

Species in the Upper Eocene assemblage and described from the Miocene of Australia are as follows:

Alabamina tenuimarginata (Chapman, Parr and Collins)
Alabamina tuberculata var. *australiensis* (Chapman, Parr and Collins)
Astrononion australe Cushman
Carpentaria rotaliformis Chapman and Crespin
Clavulinoides szaboi (Hantken) var. *victoriensis* Cushman
Discorbis margaritiferus (Heron-Allen and Earland)

Eponoides scabriculus (Chapman)
Frondicularia lorifera Chapman
Gaudryina (*Pseudogaudryina*) *crespinae* Cushman
Guttulina (*Sigmoidina*) *silvestrii* Cushman and Ozawa
Hauerina tateana (Howchin)
Sigmoilina chapmani Cushman
Sigmoilina victoriensis Cushman

Puebla Formation. Foraminifera are not as common in the argillaceous sediments which comprise the Puebla Formation as in the more calcareous beds of the underlying Jan Juc Formation. Two assemblages of species are present within the Formation. No characteristic species are present in the lower portion of the Formation which includes approximately 47 ft. of sediments directly overlying the Jan Juc Formation. A few species described from the Upper Eocene have been identified together with one—*Lamarckina glencoensis*—which is otherwise a characteristic species of the Jan Juc Formation. This species was found in sample BR.8. A few Miocene species are associated with these forms.

The Upper Eocene forms include:

Bolivina victoriensis Cushman
Cassidulina armosa Bandy
Cibicides umbonifer Parr
Glabratella crassa Dorreen
Lamarckina glencoensis Chapman and Crespin

The Miocene species include:

Clavulinoides szaboi (Hantken) var. *victoriensis* Cushman
Eponides scabriculus (Chapman)
Reussella pulchra Cushman
Reussella spinulosa (d'Orb.)
Sigmoilina victoriensis Cushman

In sample BR.9, which is 40 ft. stratigraphically higher than BR.8 in Section 7, and in BR.11 and BR.12, still higher in the section, the typical Lower Miocene "Balcombian" species *Cibicides victoriensis* and *Operculina victoriensis* make their first appearance.

The beds of the Zeally Limestone Member contain a characteristic assemblage of species which has been described chiefly from the *Lepidocyclina*-bearing beds and their equivalent in Victoria. The species include:

Calcarina verriculata (Howchin and Parr)
Crespinella umbonifera (Howchin and Parr)
Elphidium howchini Cushman
Elphidium parri Cushman
Gypsina howchini Chapman
Planorbulinella inaequilateralis (Heron-Allen and Earland)
Planorbulinella plana (Heron-Allen and Earland)
Operculina victoriensis Chapman and Parr

Time Rock Units

"Anglesean Stage" (Pre-Janjukian)

The discussion on page 111 shows that by definition and usage three interpretations may be given to the term "Anglesean Stage", namely, as the stratigraphical interval represented by:

(a) the Anglesea Member;
(b) the Demon's Bluff Formation;
(c) the Demon's Bluff Formation, the Boonah Sandstone and the Eastern View Coal Measures.

No fossils of age significance are known to occur in the Anglesea Member, or the beds which immediately overlie it; moreover, it rests upon unfossiliferous sediments. Similar remarks apply to the Demon's Bluff Formation except that the age of the beds which overlie it can be closely determined. It would be most unusual to adopt an interpretation such as (c) because many of the beds are non-marine and the coal measures rest upon Jurassic sediments.

Therefore, strictly, none of the interpretations is satisfactory; however, because the name is in the literature it was thought that it might be retained if the stratigraphic interval represented by any one of them could be accurately defined and were, in fact, of Stage rank. Obviously, this cannot be done on the basis of evidence available in the type areas.

It appeared probable that the relationship of the "Anglesean" to contemporaneous and older Tertiary marine sediments could be established by examination of the coastal sections at Brown's Creek and Dilwyn Bay. (Brown's Creek, 9 miles north-west of Cape Otway, is 42 miles south-west of Eastern View, the most westerly locality described in this paper.)

C. A. Wilkinson, in his report (1865) to the Director of the Geological Survey of Victoria, gave a very good account of the Tertiary Sections exposed between Cape Otway and the Gellibrand River. The only sections to which he made no specific reference are those between Johanna River and Rotten Point (Brown's Creek is between these two localities). His description of sections between Castle Cove and Cape Otway have not been improved upon and from the field man's point of view all his notes are useful. Wilkinson commented upon the similarity of certain "dark, almost black" beds with the beds exposed east of Point Addis (Demon's Bluff). Writing about these beds he states: ". . . wherever you examine them numerous small branching markings like algae are present".

George Baker (1943, 1944, 1950, 1953) has given detailed descriptions of the rocks exposed from Moonlight Head westwards. Section 25 is compiled from his descriptions and figures.

Fossils from the grit 35 ft. above the base of the Pebble Point Formation were described by Teichert (1943) and Singleton (1943).

From an examination of the nautiloids Teichert (p. 258) concluded that the rocks "might even be as old as Upper Cretaceous but since we are apparently concerned with the basal part of a continuous sequence which passes upwards into sediments of Miocene age and since the genus *Nautilus* is not known from strata of pre-Tertiary age, an Eocene age for the nautiloid beds seems to be the most likely assumption".

From an examination of the mollusca Singleton (p. 277) concluded: " . . . they may be tentatively referred to the Lower Eocene with a possibility that they may be as old as Paleocene".

The conclusions of Glaessner and Parr (in Baker, 1943) based on determination of the foraminifera were not inconsistent with those reached by the other authors.

Glaessner (1947) examined fossil Crustacea from the Pebble Point Formation and Rivernook Member, stated that they were not of much value for precise determination of age, but commented on their similarity.

SECTION 25

Lower Part of Section of Tertiary beds between Moonlight Head and Gellibrand River (after Baker)

Group	Formation	Member	Thickness	Beds
			—	Sandy clays and ironstone.
Wangeripp Group	Dilwyn Clay	Princetown Member	40 ft.	Dark grey to black sandy clays with markings resembling "algal" remains, and *Cyclammina*.
			35 ft.	Unfossiliferous friable red and yellow ferruginous sandstone.
			60 ft.	Clay to shale, in part bituminous. Some polyzoal remains and "algal" markings.
			4/5 ft.	*Trochocyathus* bed. Sandstone with abundant corals, mollusca (*Voluta* and *Dentalium*) and shark's teeth.
			40 ft.	Carbonaceous clay, yellow to grey on weathered surfaces; black when wet.
			5 ft.	*Turritella* bed. Sandstone.
			250 ft.	Carbonaceous clays; abundant copiapite in places; structures resembling "algal" remains.
		Rivernook Member	20 ft.	Glauconitic clay (gritty mudstone); Glaessner (1947).
			500 ft.	Carbonaceous clays, etc. (includes hard ferruginous sandstone with echinoids and pelecypods)—(about middle according to Baker 1943, Fig. 2, p. 243).
	Pebble Point Formation		15 ft.	Ferruginous sandy beds with minor beds of clay.
			—	Fossiliferous grit with ferruginous/argillaceous cement.
			35 ft.	Friable sandy ironstone with bands of grit and veins of limonite.
			—	Jurassic.

In 1947 Teichert described a genus *Deltoidonautilus* from the Clifton Formation (higher in the section than the Princetown Member) and referred to it in the following terms: "No representative of this genus appears ever to have been found in beds younger than Eocene, and, wherever the exact place in the Eocene is known, the species occur in the lower and middle part of that Series".

The palaeontological evidence cited above together with that discussed by Baker (1953) leaves little room for doubt that the fossil bed in the Pebble Point Formation is of Palaeocene Age. It is possible that the Dilwyn Clay up to and including the Rivernook Member may also be Palaeocene. The Dilwyn Clay above the Rivernook Member is clearly not younger than Eocene and may be Lower Eocene. Baker (1953) considers that the Princetown Member at the top of the Dilwyn Clay is Lower Eocene.

Reeves and Evans (1949) measured sections in this locality and concluded that some of the beds were thinner than represented by Baker. Their observations are summarized in Section 26.

Though Chapman (1904) had recorded *Cyclammina* in beds at Brown's Creek lithologically similar to those at Dilwyn Bay, there is no reference to this foraminifer in any later papers about the district. Baker (1953) confirms that Parr did not find *Cyclammina* in any of the material collected by him and it was not present in the samples examined by Miss Crespin for Reeves and Evans.

Parr (1947) described *Hantkenina alabamensis* subsp. *compressa* from Brown's Creek in beds lithologically different from those referred to by Chapman (1904). This genus also was not identified by Parr in the material collected by Baker.

SECTION 26

Group	Formation	Thickness	Lithology
Wangeripp Group	Dilwyn Clay	100 ft.	Grey and yellowish brown sands overlying ferruginous gravel.
		55 ft.	Chocolate clays with natrojarosite.
		1 ft.	*Trochocyathus* beds.
		50 ft.	Chocolate clays, etc.
		1 ft.	Sandstone with *Turritella*.
		100 ft.	Chocolate clays.
	Pebble Point Formation	90/100 ft.	Ferruginous grits and ironstones.
		15 ft.	Carbonaceous clay with pyrite (exposed at sea-level at Point Margaret).
		—	Jurassic.

The apparent absence of *Cyclammina* and *Hantkenina* from the beds exposed west of Moonlight Head has been investigated by the authors as also have the occurrences at Brown's Creek. The results were summarized in an earlier paper (Raggatt and Crespin, 1952) and are set out hereunder.

On the south-eastern side of Dilwyn Bay (8 miles west of Johanna River) the following section—Section 27—is exposed in the sea cliffs.

SECTION 27

	Thickness ft.	in.		
Dilwyn Clay (Lower Part)	100	–	Some slumping, partly estimated.	Purplish-grey, sandy siltstone.
	70	–	To top of main cliff.	
Pebble Point Formation	27	–	Brown, fine sandstone with lenses of coarse quartz sandstone; concretions 1 in. in diameter and up to 6 in. in length.	
	1	6	Lenticular, shelly fine conglomerate.	
	40	–	Fine conglomerate to coarse, brown sandstone.	
	6	–	Brown sandstone irregularly cemented (ferruginous).	
	50	–	Fine conglomerate to coarse sandstone alternating with black to purplish-brown, fine sandstone, clayey in places.	

This section is illustrated in Baker (1950, Plate II, fig. B) in which the siltstones, 70 ft. thick, can be identified as a light band. The "shelly, fine conglomerate" is the same as Baker's "fossiliferous grit".

The siltstones at the top of the Section (the uppermost 30 ft.) contain *Ammodiscus* sp. (small), *Arenobulimina* sp., *Cyclammina rotundata* Chapman and Crespin, *Cyclammina* sp. (small), *Cibicides* cf. *umbonifer* Parr, *Guttulina irregularis* (d'Orb.). *Cyclammina* is plentiful and can be recognized easliy by eye.

Approximately at the same time as the authors discovered *Cyclammina* at this locality Baker (1953) also found it (near the mouth of the Gellibrand River) in the Princetown Member; i.e. at the top of the Dilwyn Clay.

Between Rotten Point and the mouth of Johanna River the following section—Section 28—is exposed.

SECTION 28

	Thickness ft.	in.	
Exposed in cliffs east of mouth of Johanna River	–	–	Dune sand.
	27	–	Shelly silty limestone.
	1	3	Limestone.
	1	–	Silty limestone.
Exposed in gullies between mouth of Brown's Creek and mouth of Johanna River.	18	–	Well-bedded, pebbly brown sandstone.
	4	–	Grey, micaceous, sandy clay.
	12	–	Alternating light and dark grey clayey marl.
	62	–	Light grey to black shelly clayey marl.
	9	–	Glauconitic, shelly sand with *Notostrea* (abundant in upper 5 ft.) and *Hantkenina*.
	25	–	Grey to dark brown clay with abundant shelly fossils.
	30	–	Estimated; outcrops obscured by dune sand.
Exposed in wash-out above head-land between Rotten Point and Brown's Creek.	15	–	Medium to coarse brown sandstone.
	15	–	Pale purple siltstone at base overlain by brown sandstone with thin lenses of light grey clay.
	41	–	Pale purple, silty sandstone.
	5	–	Purple to black, silty sandstone. Quartz pebbles up to 1½ in. in diameter in lower foot.
	2	–	Grey to purplish-brown shale with *Cyclammina*.
	2	–	Pale purple, silty sandstone with lenticular, medium to coarse sandstone. Platey, ferruginous layers.
		6/12	Quartz conglomerate; pebbles ¼ to ½ in. in diameter.
	44	–	Medium to coarse, loosely cemented yellow to brown sandstone.
	40	–	Light grey, silty sandstone; white quartz pebbles ½ in. to 1 in. in diameter.
		6/12	Black sandy siltstone.
		–	Arkosic sandstone (Jurassic).
	354	9	

This section shows the relationship of the beds with *Cyclammina*, described by Chapman (1904), to those with *Hantkenina*, referred to by Parr (1947). Both of these foraminifera have been identified by Crespin in samples collected from the section by Raggatt. The typical Jan Juc Formation foraminifera *Victoriella plecte* and *Lamarckina glencoensis** occur with *Hantkenina* at Brown's Creek.

In addition to *Hantkenina* the beds contain a rich foraminiferal assemblage which is characteristically Eocene. For example, the silty limestone at the top of the section contains:

Anomalina perthensis Parr
Angulogerina subangularis Parr
Bolivinopsis crespinae Parr
Buliminella westraliensis Parr
Cibicides pseudoconvexus Parr
Discorbis assulatus Cushman
Genus aff. *Eoannularia*
Globigerina mexicana Cushman
Globigerina triloculinoides Plummer

*See footnote p. 128.

Heronallenia pusilla Parr
Guembelina venezuelana Nuttall var. *rugosa* Parr
Lagena terrilli Parr
Pseudobulimina glaessneri Howe and Roberts

Also present are many undescribed species of *Angulogerina* and *Cibicides* which have been noted by Crespin in beds of Eocene age at Christie's Beach, Port Noarlunga, and Maslin Beach, Aldinga, South Australia. These new species are also present at Bird Rock.

Some of the species listed above were identified by Parr in the King's Park Bore, Perth, and regarded by him—at the suggestion of one of us (I.C.)—(see Parr, 1938, p. 70) as Upper Eocene; some have been identified by Cushman and others from the Eocene of America.

If the Section at Brown's Creek (No. 28) is compared with that near Dilwyn Bay (No. 25) it will be seen that the unfossiliferus sandstones at the base of the Tertiary sequence at Brown's Creek are the equivalents of Baker's Pebble Point Formation which contains a bed with Palaeocene marine fauna. Baker (1950, p. 20) has in fact identified the Pebble Point Formation as far east as Moonlight Head (6 miles west of Johanna River), and has noted that east of Point Lucton it is unfossiliferous. At Brown's Creek above the sandstone the sequence is (i) silts with *Cyclammina*, (ii) glauconitic sands and clays with *Hantkenina*, (iii) silty limestone with Eocene foraminifera.

Comparing the Sections at Brown's Creek and Dilwyn Bay with that in the Torquay-Eastern View district there is little doubt—

(i) that the Pebble Point Formation can be correlated with the Eastern View Coal Measures and the Boonah Sandstone, or the Boonah Sandstone alone (the Coal Measures being absent or represented by the carbonaceous sands or clay at the base of the Pebble Point Formation).

Reeves and Evans independently reached a similar conclusion in 1949; they wrote: "the grits, clays and lignite beds at the base of the Anglesean may be correlated with the clays and pebbly grits exposed north-west of Moonlight Head and at Castle Cove".

(ii) that the Demon's Bluff Formation, or part of it, can be correlated with the siltstones (some with *Cyclammina*) at Brown's Creek and Dilwyn Bay.

To a large extent these suggested correlations are based on lithology, and lithogenesis. In considering their value for the purposes of age determination, it is necessary to recognize that formation boundaries may transgress time boundaries. The correlations assume also that beds of the same lithology were deposited approximately synchronously in marine and freshwater environments at different localities (e.g. Pebble Point Formation and Boonah Sandstone). The palaeogeography of the lower Tertiary in southern Victoria suggests that synchronous deposition in marine and freshwater environments occurred over wide areas.

It needs to be borne in mind also that *Hantkenina* has not so far been found in the Princetown area and that the fossils typical of horizons in the Dilwyn Clay and Pebble Point Formation have not been found east of the type localities for those formations. For these reasons the age of the beds below those with *Hantkenina* at Johanna River and the age of the beds above the fossil bed in the Pebble Point Formation cannot be stated with certainty. Also, of course, close correlation between the beds at these two localities is difficult.

On the basis of palaeontological evidence there seems little doubt that—

(1) The Jan Juc Formation with *Hantkenina* is of Upper Eocene age.

(2) The Pebble Point Formation (and, therefore, approximately the beds with which it is correlated) are of Palaeocene age.

(3) The lower part of the Dilwyn Clay is not younger than Lower Eocene and may be in part Palaeocene.

These conclusions do not allow the time interval represented by the Demon's Bluff Formation being determined within narrow limits. There is little doubt it is older than Upper Eocene but it may represent the whole of the Middle and Lower Eocene and, if the lower part of the Dilwyn Clay is Palaeocene, part of the Palaeocene as well.

From this discussion it is concluded that none of the possible uses of "Anglesean Stage" referred to on p. 131 is satisfactory: (a) and (b) because the stratigraphic interval cannot be accurately defined, and (c) because it represents far too great a time interval. The term should, therefore, be discarded and new pre-Janjukian stages defined. The information available does not allow of this being done immediately.

Janjukian Stage

The type section of the Janjukian Stage as defined by Hall and Pritchard (1902) and by Singleton (1941) is exposed between the mouth of Spring Creek (Jan Juc Point) and Rocky Point. As defined by these authors it is, in fact, the stratigraphical interval represented by the Torquay Group of this paper.

The type section of the "Balcombian Stage" at Balcombe Bay, Mornington, is a very unsatisfactory one, and as has been briefly discussed earlier in this paper there has been disagreement about its position relative to the Janjukian. However, it has been generally accepted for some time now that the Balcombian overlies the Janjukian but the precise relationship has never been determined. Singleton, in fact, considered that the Batesfordian lies between the Janjukian and the Balcombian. This conclusion is not supported by the work of one of us on samples from numerous bores and a deep shaft in East Gippsland (I.C., 1941, 1943) which suggests that beds with *Lepidocyclina* (Batesfordian) lie within beds with a Balcombian fauna. This is suggested also by results obtained from determination of the foraminifera in the beds above and below the Batesford limestone.

The earlier discussion in this paper, and the diagrams illustrating correlation and distribution of foraminifera in the Torquay Group show that the fauna of its upper part (Puebla Formation) is typically "Balcombian". (Table 14 and Fig. 5.) As, by definition, it is part of the Janjukian, there seems little doubt that the Janjukian and Balcombian as at present defined overlap each other. It is, therefore, proposed to re-define the Janjukian.

As pointed out on p. 123, in most places the contact between the Jan Juc and Puebla Formations is sharply defined and marks a significant change in conditions of sedimentation which is expressed by change in lithology, marked reduction in fossil content, and in the development of glauconite. Glauconite is very abundant, in the upper part particularly, of the Jan Juc Formation, and scarce in the Puebla Formation. Except in the bottom 18 ft., at Fisherman's Steps and Bird Rock, glauconite is, in fact, virtually absent from the Puebla Formation.

The analysis of the microfauna of the Torquay Group shows that the Jan Juc Formation contains ten species of foraminifera, which do not occur in overlying beds:

Bulimina pupula Stache
Dimorphina janjukensis Crespin
Frondicularia victoriae Crespin
Hantkenina alabamensis (Cushman) subsp. *compressa* Parr
Massilina torquayensis Chapman
Quinqueloculina singletoni Crespin
Quinqueloculina ornithopetra Crespin
Vaginulinopsis gippslandicus (Chapman and Crespin)
Victoriella plecte (Chapman)

The following smaller species are also restricted to the Formation:

Alabamina obtusa (B. and H.) var. *westraliensis* Parr
Bolivinopsis crespinae Parr
Cibicides pseudoconvexus Parr
Discorbis assulatus Cushman
Glabratella sp. 1
Lagena perthensis Parr
Lagena sp. 1
Nonionella hantkeni (Cushman and Applin)

It may be noted that, as pointed out on page 80 of this paper, Tate and Dennant (1895) had suggested that two separate faunas might be represented in the Bird Rock cliffs. They referred to mega-fossils and it will be of considerable interest to see whether the conclusions reached by the authors are supported by other workers whose main interest is in the larger fossils.

For the reason that the Formation contains so many foraminifera of restricted range, including a subspecies of *Hantkenina alabamensis* (a species known to have a restricted range elsewhere) and because also the Formation clearly represents a significant part of geological time, characterized by conditions differing significantly from that before and after its deposition, *the Janjukian Stage is defined as the stratigraphical interval represented by the Jan Juc Formation, and characterized by the microfaunal assemblages listed above.*

The change from pre-Janjukian to Janjukian conditions of sedimentation as has been described (pp. 123, 136) was most marked; all criteria which could be used to define the base of the Janjukian would lead to the same conclusion. In determining the boundary between the Janjukian and the "Balcombian" it can be argued that, because at Bird Rock and Fisherman's Steps sediments up to 18 ft. above the top of the Jan Juc Formation have some lithological features (ovoid pellets and glauconite) in common with the Formation, the Janjukian Stage might be defined in terms somewhat different from those used above. This possibility is admitted and it is accepted that there may be differences of opinion as to what criteria should be given the most weight in drawing boundaries which cannot but be arbitrary. In placing the upper limit of the Janjukian at the top of the Jan Juc Formation reliance has been placed mainly on two criteria:

(i) none of the species restricted to the Janjukian as defined herein has been found above the top of the Formation;
(ii) there is no convenient or definable surface higher than the top of the Jan Juc Formation at which a boundary could be drawn.

The evidence available is insufficient to permit re-definition of the Balcombian.

There seems little doubt that the Janjukian Stage as defined above is Upper Eocene in age. According to Grimsdale (1951) *Hantkenina alabamensis* is

restricted to the Upper Eocene (Jackson) of the Gulf of Mexico and Carribean areas in America and to the Upper Eocene (Bartonian) of the Middle East. Bronnimann (1950) gives a similar age for the species in the British West Indies and at the same time makes comments on Parr's *H. alabamensis* subsp. *compressa*. *Guembelina multicellaris* was described by Hussey (1949) from the Upper Eocene of Louisiana. Also of importance is the occurrence of *Globigerinoides index*, which occurs with *Hantkenina* and which Finlay described from the Middle Eocene (Bortonian Stage) of New Zealand. Grimsdale records this species from the Upper Eocene of the Gulf of Mexico and Carribean areas and of the Middle East. "*Globigerinella*" *micra* (*Nonion micrus*) (Cole) (1927) is also a typical Eocene species in the above area. The use of the rapidly moving pelagic foraminifera such as *Hantkenina*, *Globigerina* and *Globotoralia* in long-range correlations in the Lower Tertiary is becoming of considerable importance where the larger forms are absent.

Amongst the ten species which are so characteristic of the Formation, except for *Hantkenina alabamensis* subsp. *compressa*, probably the most important is *Victoriella plecte*. It is not affected by facies changes. Its recent discovery in north-west Australia in association with the typical Eocene genus *Discocyclina* suggests that it is a reliable index fossil for the Upper Eocene in Australia.

There is room for speculation concerning the age of the beds immediately above the zone of *Hantkenina*. It may be that in southern Victoria, at least, this zone does not represent the absolute top of the Eocene because—

(i) the beds above the *Hantkenina* zone at Johanna River contain a micro-fauna which is apparently Eocene, and which is familiar to that found at Bird Rock;

(ii) *Lamarckina glencoensis*, which is common in the beds of the Jan Juc Formation, also occurs in the basal beds of the Puebla Formation in the Bird Rock Section.

The presence of beds with an Eocene fauna above the *Hantkenina* zone at Johanna River also leads to the conclusion that the Jan Juc-Puebla contact represents a non-sequence, as indeed it must be if the Puebla Formation is, as the palaeontological evidence suggests, Lower Miocene.

The precise stratigraphical position of the Batesford Limestone (which contains *Lepidocyclina*) in relation to the top of the Jan Juc Formation is not known but it is certainly above it. As the species of *Lepidocyclina* found at Batesford are regarded as Lower Miocene in age (Crespin, 1936, 1953) the beds between the two fossil zones, that is between the *Lepidocyclina* beds and the zone of *Hantkenina* may possibly be Lower Oligocene in age but this possibility is not supported by palaeontological evidence.

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Explanation of Plates

PLATE IV

Fig. 1.—Aerial view of Coal Seams on sea floor at Eastern View between Spout Creek and Coalmine Creek.
Fig. 2.—Demon's Bluff Formation from Anglesea Lookout, looking westerly. *A*: Angahook Member; *B*: Addiscot Member. *C*: Anglesea Member.
Fig. 3.—Disconformable contact between Addiscot and Anglesea Members of Demon's Bluff Formation at Demon's Bluff.

PLATE V

Fig. 1.—Conformable contact between Addiscot and Anglesea Members of Demon's Bluff Formation at The Black Rocks.
Fig. 2.—Rocky Point from Rock Platform, showing Puebla Formation and Jan Juc Formation (Pt. Addis Limestone Member).
Fig. 3.—Fisherman's Steps, showing contact of Puebla and Jan Juc Formations and markers in Jan Juc Formation.

PLATE VI

Fig. 1.—Bird Rock and Adjacent Point, looking west.
Fig. 2.—View from Bird Rock looking west towards Fisherman's Steps.
Fig. 3.—Jan Juc Point, south end of Torquay Surfing Beach. Puebla Formation, Zeally Limestone Member.

PLATE VII

Fig. 1.—*Bathysiphon angleseaensis* Crespin. Demon's Bluff, Anglesea. Front view. × circ. 16·5.
Fig. 2.—*Ammodiscus parri* Crespin. No. 1 Bore, Parish of Bengworden South, Gippsland, at 2,538 feet. Front view. × circ. 13·5.
Fig. 3.—*Cyclammina incisa* Stache. Demon's Bluff, Anglesea. Front view. × circ. 16·5.
Fig. 4.—*Cyclammina paupera* Chapman. Demon's Bluff, Anglesea. Front view. × circ. 18.
Fig. 5.—*Cyclammina rotundata* Chapman and Crespin. Demon's Bluff, Anglesea. *a*, front view, × circ. 18; *b*, apertural view, × 15.
Fig. 6.—*Quinqueloculina singletoni* Crespin. Base of Bird Rock Cliff, Torquay. *a*, dorsal view; *b*, ventral view. × circ. 18.
Fig. 7.—*Quinqueloculina ornithopetra* Crespin. Base of Bird Rock Cliff, Torquay. *a*, dorsal view; *b*, apertural view, showing bifid tooth. × circ. 15.
Fig. 8.—*Massilina torquayensis* (Chapman). Base of Bird Rock Cliff, Torquay. Dorsal view of gerontic specimen. × circ. 17·5.
Fig. 9.—*Vaginulinopsis gippslandicus* (Chapman and Crespin). No. 3 Bore, Parish of Glencoe, Gippsland, at 180 feet. Front view. × circ. 15.
Fig. 10.—*Frondicularia victoriae* Crespin. Cliff section between Fisherman's Steps and Bird Rock, Torquay. Front view. × circ. 71.

Fig. 11.—*Dimorphina janjukensis* Crespin. Base of Bird Rock Cliff, Torquay. Front view. × 20.

Fig. 12.—*Fulmina pupula* Stache. Cliff section between Fisherman's Steps and Bird Rock, Torquay. Front view, × 30.

Fig. 13.—*Lamarckina glencoensis* Chapman and Crespin. No. 3 Bore, Parish of Glencoe, Gippsland, at 100 feet. *a,* dorsal view; *b,* ventral view. × 28.

Fig. 14.—*Sherbornina atkonsoni* Chapman. Bell's Headland, west of Torquay. Front view. × 33.

Fig. 15.—*Victoriella plecte* (Chapman). Base of Bird Rock Cliff, Torquay. View showing position of aperture. × 15.

Tables

Distribution of Foraminifera in samples from measured Sections.

Text Figures


N
Spout Ck.
Coalmine Ck.
0
1000
2000
3000
4000 FEET

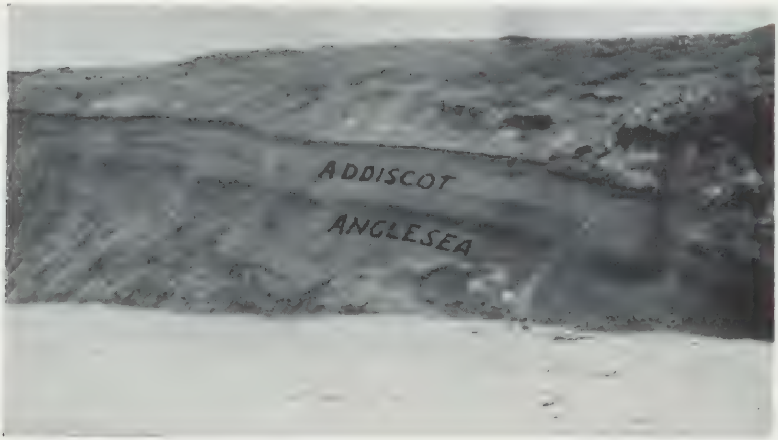
1


POINT ROADKNIGHT
BOAT
HARBOUR
SOAPY
ROCKS
"A"
"B"
"C"

2


ADDISCOT

3


ADDISCOT
ANGLESEA

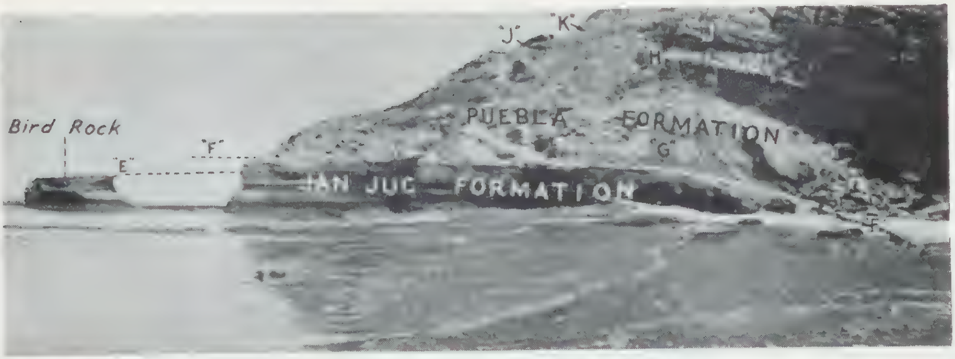
1


PUEBLA FORMATION
JAN JUC FORMATION (PT. ADDIS LST. MEMBER)

2


"H" "J" "K"
"G"
PUEBLA FORMATION
JAN JUC FORMATION

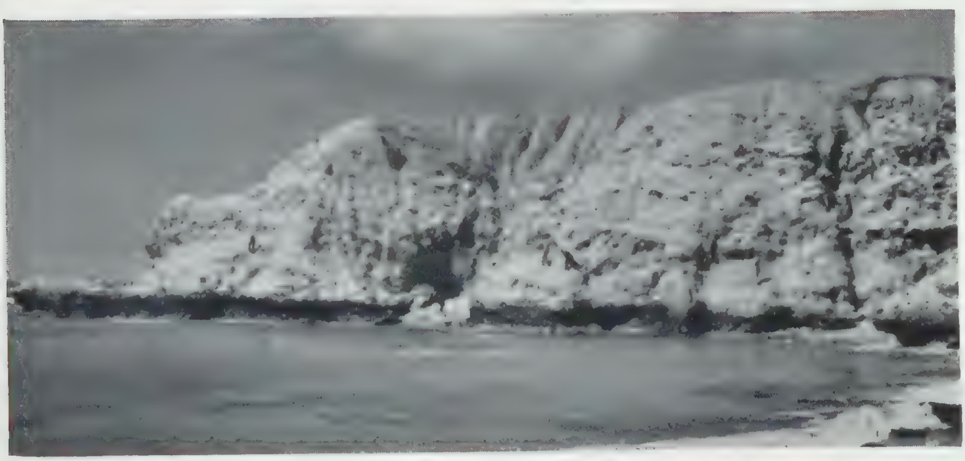
3


"J"
"K"
"H"
Bird Rock
"F"
"E"
PUEBLA FORMATION
"G"
JAN JUC FORMATION

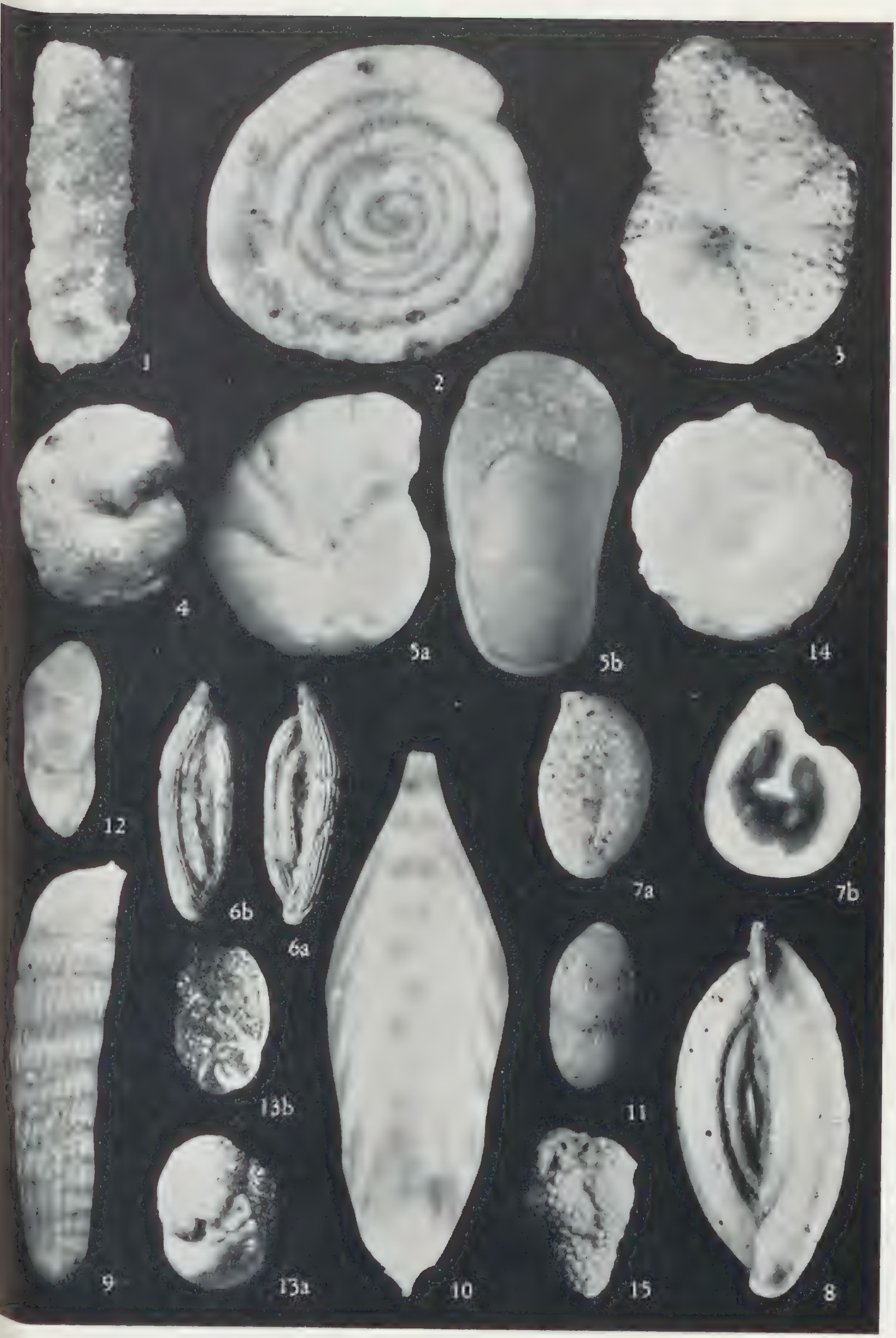
1


"J"&"K"
"H"
PUEBLA FORMATION
JAN JUC FORMATION

2



3


1
2
3
4
5a
5b
14
12
6b
6a
7a
7b
13b
11
9
13a
10
15
8

Corrigenda

TABLE IV—

For—*Calcarine* cf. *verriculate* read *Calcarina* cf. *verriculata*
Genus aff. *Eoannularia* read *Crespinina kingscotensis*
scalprate read *scalprata*

TABLE V—

For—*pulsilla* read *pusilla*

TABLE VI—

For—Genus aff. *Eoannularia* read *Crespinina kingscotensis*

TABLE VII—

For—*Mackayi* read *mackayi*
Znomalina read *Anomalina*
repandux read *repandus*
Globor oralia read *Globorotalia*
Lieubueslla read *Liebusella*

TABLE X—

For—*alabamensus* read *alabamensis*
pseudocultrata read *pseudocultratus*
Eoannularia sp. read *Crespinina kingscotensis*

TABLE XIII—

For—*Planularia* read *Planulina*

TABLE XVI—

For—*Karreviella* read *Karreriella*

TABLE I

Foraminifera	E6	E5	E4	E3	E2	E1	E7	E8	E9	E10	E11	E12	E13	E14	E15	E16
Cyclammina incisa	×	×	×	×	×	×	×	—	×	×	×	×	×	×	×	×
Ammodiscus incertus var. *macilenta*	—	—	×	×	×	×										
Cibicides sp.	—	—	×	×	×	×	×	—	×	×	×	×	×	×	×	×
Cyclammina paupera	—	—	×	×	×	—	×	—	×	×	×	×	×	×	×	×
Cyclammina rotundata	—	—	×	×	×	×										
Ammodiscus cf. *parri*	—	—	—	—	—	—	—	×	×	—	—	—	×			
Cyclammina sp.	—	—	—	—	—	—	—	×	×	—	—	—	—	—	—	×
Dorothia cf. *parri*	—	—	—	—	—	—	—	—	×	×	×	×	—	—	×	
Bathysiphon angleseæensis	—	—	—	—	—	—	—	—	—	×	×	×	×	×	×	
cf. *Lituola simplex*	—	—	—	—	—	—	—	—	—	×	×	×				

TABLE II

Foraminifera	W.1	W.2	W.3
Cyclammina incisa	x	x	x
Bathysiphon angleseaensis	—	x	x
Dorothia cf. *parri*	—	x	x

TABLE III

Foraminifera	W.4	W.5	W.6	W.7	W.8	W.9	W.10
Cyclammina incisa	×	×	—	×	×	×	×
Ammodiscus cf. *parri*	—	×	×	×	×	×	×
Cyclammina sp.	—	—	×				
Dorothia cf. *parri*	—	—	—	—	×		
Spiroplectammina cf. *mississippiensis* ..	—	—	—	—	—	×	
Cyclammina rotundata	—	—	—	—	—	—	×

TABLE IV

Foraminifera	PA 4	PA 3	PA 2	PA 1	E112C	PA 6	PA 15	PA 7	PA 8b	PA 12	PA 13	PA 14	PA 9	PA 10	E110D	E110C	E110B	E110A	PA 11
Cyclammina sp.	x	x	x	x	x														
Ammodiscus sp.	-	-	x	-	-														
Bathysiphon cf. angleseaensis	-	-	x	-	-														
Amphistegina sp.	-	-	-	-	-	x	x	x	x	x	x	x							
Calcarina sp. cf. mackayi	-	-	-	-	-	x	x	x	x	x	x	x	-	x	x	-	-	-	x
Cibicides vortex	-	-	-	-	-	x	-	x	x	x	x	x							
Gaudryina (Pseudogaudryina) crespinae	-	-	-	-	-	-	x	-	-	-	x	-	x	x	-	-	-	-	x
Anomalina subnonionoides	-	-	-	-	-	-	-	x	x	x	-	-	-	x					
Calcarina cf. verriculata	-	-	-	-	-	-	-	x	-	x	x	-	x						
Cassidulina oblonga	-	-	-	-	-	-	-	x											
Cassidulina subglobosa var. horizontalis	-	-	-	-	-	-	-	x	x	-	x	-	x	x	x				
Cibicides sp. 1	-	-	-	-	-	-	-	x	-	-	x	-	x	x	-	x	-	x	x
Elphidium cf. pseudoinflatum	-	-	-	-	-	-	-	x	x	x	-	x	x						
Genus aff. Eoannularia	-	-	-	-	-	-	-	x	x	x	x								
Gypsina globulus	-	-	-	-	-	-	-	x	-	x									
Nodosaria sp.	-	-	-	-	-	-	-	x											
Planorbulina macphersoni	-	-	-	-	-	-	-	x	x	x									
Asterigerina cyclops	-	-	-	-	-	-	-	-	x										
Carpentaria sp.	-	-	-	-	-	-	-	-	x	-	-	-	-	x					
Cassidulina armosa	-	-	-	-	-	-	-	-	x	-	-	-	-	x					
Cassidulinoides chapmani	-	-	-	-	-	-	-	-	x	-	-	x	x	x					
Cibicides cf. lobatulus	-	-	-	-	-	-	-	-	x										
Cibicides pseudoconvexus	-	-	-	-	-	-	-	-	x										
Cibicides umbonifer	-	-	-	-	-	-	-	-	x	-	-	x	x	x					
Elphidium howchini	-	-	-	-	-	-	-	-	x										
Guembelina sp.	-	-	-	-	-	-	-	-	x										
Gyroidina scrobriculata	-	-	-	-	-	-	-	x											
Notorotalia sp. 1	-	-	-	-	-	-	-	-	x	-	-	-	-	x					
Polystomellina sp. nov.	-	-	-	-	-	-	-	-	x	x									
Pseudopolymorphina rutila var. parri	-	-	-	-	-	-	-	-	x										
Rotorbinella finlayi	-	-	-	-	-	-	-	-	x	-	-	-	-	x					
Stomatorbina torrei	-	-	-	-	-	-	-	-	x	x	-	-	-	x					
Victoriella plecte	-	-	-	-	-	-	-	-	x	x									
Angulogerina sp. 2	-	-	-	-	-	-	-	-	-	-	-	x	-	x					
Angulogerina australe	-	-	-	-	-	-	-	-	-	-	-	-	x	x					
Angulogerina cf. wilcoxensis	-	-	-	-	-	-	-	-	-	-	-	-	x						
Anomalina perthensis	-	-	-	-	-	-	-	-	-	-	-	-	x	x	-	x			
Bolivina scalprata var. retiformis	-	-	-	-	-	-	-	-	-	-	-	-	x						
Bolivina victoriana	-	-	-	-	-	-	-	-	-	-	-	-	x	x	-	-	-	x	
Cibicides sp. 2.	-	-	-	-	-	-	-	-	-	-	-	-	x	x					
Cibicides sp. 3.	-	-	-	-	-	-	-	-	-	-	-	-	x						
Clavulinoides szaboi var. victoriensis	-	-	-	-	-	-	-	-	-	-	-	-	x	x	x	x	x	-	x
Dentalina cf. obliqua	-	-	-	-	-	-	-	-	-	-	-	-	x						
Discorbis bertheloti var. nov	-	-	-	-	-	-	-	-	-	-	-	-	x	x	x				
Discorbis cf. patelliformis	-	-	-	-	-	-	-	-	-	-	-	-	x	x	x				
Ehrenbergina healyi	-	-	-	-	-	-	-	-	-	-	-	-	x						
Eponides scabriculus	-	-	-	-	-	-	-	-	-	-	-	-	x						
Frondicularia victoriae	-	-	-	-	-	-	-	-	-	-	-	-	x						
Frondicularia sp. nov.	-	-	-	-	-	-	-	-	-	-	-	-	x						
Globigerina cf. bulloides	-	-	-	-	-	-	-	-	-	-	-	-	x	-	x				
Globigerina triloculinoides	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	x			
Globulina gibba	-	-	-	-	-	-	-	-	-	-	-	-	x						
Heronallenia pusilla	-	-	-	-	-	-	-	-	-	-	-	-	x						
Lagena sulcata	-	-	-	-	-	-	-	-	-	-	-	-	x	x					
Nodosaria latejugata	-	-	-	-	-	-	-	-	-	-	-	-	x						
Plectofrondicularia cf. striata	-	-	-	-	-	-	-	-	-	-	-	-	x						
Sigmoidella bortonica	-	-	-	-	-	-	-	-	-	-	-	-	x	x	x				
Siphonina australis	-	-	-	-	-	-	-	-	-	-	-	-	x	x	-	-	-	-	x
Sphaeroidina bulloides	-	-	-	-	-	-	-	-	-	-	-	-	x	x	-	-	-	-	x
Spiroplectammina mississippiensis	-	-	-	-	-	-	-	-	-	-	-	-	x	x					
Vaginulina sp. 1	-	-	-	-	-	-	-	-	-	-	-	-	x	x					
Anomalina ammonoides var. acuta	-	-	-	-	-	-	-	-	-	-	-	-	x	x					
Angulogerina cuneata	-	-	-	-	-	-	-	-	-	-	-	-	-	x					
Angulogerina cf. halkyardi	-	-	-	-	-	-	-	-	-	-	-	-	-	x					
Bolivina aff. garretti	-	-	-	-	-	-	-	-	-	-	-	-	-	x					
Bolivina jacksonensis var. striatella	-	-	-	-	-	-	-	-	-	-	-	-	-	x					
Carpentaria rotaliformis	-	-	-	-	-	-	-	-	-	-	-	-		x					
Cibicides cf. perlucida	-	-	-	-	-	-	-	-	-	-	-	-	-	x	x	x			
Cibicides cf. victoriensis	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	x			
Dentalina subcostata	-	-	-	-	-	-	-	-	-	-	-	-	-	x					
Discorbis assulatus	-	-	-	-	-	-	-	-	-	-	-	-	-	x					
Discorbis globulo-spinosa	-	-	-	-	-	-	-	-	-	-	-	-	-	x					
Discorbis margaritiferus	-	-	-	-	-	-	-	-	-	-	-	-	-	x	x	x	-	-	x
Dorothia parri	-	-	-	-	-	-	-	-	-	-	-	-	-	x					
Enantiomarginulina sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	x
Eponides repandus var.	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	x
Frondicularia lorifera	-	-	-	-	-	-	-	-	-	-	-	-	-	x					
Glabratella sp. 1	-	-	-	-	-	-	-	-	-	-	-	-	-	x					
Globigerina cf. cretacea	-	-	-	-	-	-	-	-	-	-	-	-	-	x					
Globigerina mexicana	-	-	-	-	-	-	-	-	-	-	-	-	-	x					
Globigerina ouachitaensis	-	-	-	-	-	-	-	-	-	-	-	-	-	x					
Globigerina trilocularis	-	-	-	-	-	-	-	-	-	-	-	-	-	x					
Globorotalia chapmani	-	-	-	-	-	-	-	-	-	-	-	-	-	x					
Guttulina spicaeformis	-	-	-	-	-	-	-	-	-	-	-	-	-	x					
Lagena globosa	-	-	-	-	-	-	-	-	-	-	-	-	-	x					
Lagena gracillima	-	-	-	-	-	-	-	-	-	-	-	-	-	x					
Lagena hexagona	-	-	-	-	-	-	-	-	-	-	-	-	-	x					
Lagena quadrata	-	-	-	-	-	-	-	-	-	-	-	-	-	x					
Nodosaria arundinea	-	-	-	-	-	-	-	-	-	-	-	-	-	x					
Nonionella hantkeni	-	-	-	-	-	-	-	-	-	-	-	-	-	x					
Operculina sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	x					
Patellina corrugata	-	-	-	-	-	-	-	-	-	-	-	-	-	x					
Pullenia quinqueloba	-	-	-	-	-	-	-	-	-	-	-	-	-	x					
Robulus alabamensis	-	-	-	-	-	-	-	-	-	-	-	-	-	x	x				
Sigmoidella plummerae	-	-	-	-	-	-	-	-	-	-	-	-	-	x					
Vaginulina sp. 2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x				
Bolivina sp. 3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x				
Guttulina (Sigmoidina) silvestrii	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x				
Notorotalia cf. howchini	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x				
Operculina cf. victoriensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x			
Ammobaculites reophaciformis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x
Nodosaria cf. inconstans	-	-	-	-	-	-	-	-	-	-	-	-	-						

TABLE V

Foraminifera	B. 113	B. 112	B. 111	B. 110	B. 109	B. 108	B. 107	B. 101	B. 100	B. 99	B. 98	B. 97	B. 96	B. 95	B. 94	B. 93	B. 92	B. 91	B. 75	B. 74	B. 73	B. 72	B. 71	B. 70
Cyclammina sp.	x	x	x	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	x	-
Angulogerina australe	-	-	-	-	x	-	x	x	x	-	-	x	-	-	-	-	-	-	-	-	x			
Angulogerina sp. 2	-	-	-	-	x	-	x	-	x	-	-	x	x	-	-	-	-	-	-	-	x			
Anomalina perthensis	-	-	-	-	x	-	x	x	x	x	x	x	x	-	-	-	-	-	-	-	x	-	x	
Astrononion australe	-	-	-	-	x	-	x	-	x	-	-	-	-	-	-	-	-	-	-	-	x	x		
Bolivina crenulata	-	-	-	x	-	x	-	x																
Bolivina jacksonensis	-	-	-	-	x	-																		
Bolivina victoriana	-	-	-	-	x																			
Bolivina sp. 1	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x			
Buliminella madagascarensis var. spicata	-	-	-	-	x	-	x	-	x															
Buliminella pupa	-	-	-	-	x																			
Cassidulina cf. diversa	-	-	-	-	x																			
Cassidulinoides compacta	-	-	-	-	x	-	x	x	x															
Ceratobulimina dehiscens	-	-	-	-	x	-																		
Cibicides lobatulus	-	-	-	-	x	-	x	x	x															
Cibicides pseudoconvexus	-	-	-	-	x	-	-	-	x	x	-	x	-	-	-	x								
Cibicides umbonifer	-	-	-	-	x	-	x	-	x	-	-	x	-	-	-	-	-	-	-	-	x			
Cibicides sp. 1	-	-	-	-	x	-	x	x	x	-	-	x	x	-	-	-	x	x	x	x	x	x		
Dentalina cf. jacksonensis	-	-	-	-	x	-	-	-	-	-	-	-	x											
Dentalina cf. subcostata	-	-	-	-	x																			
Discorbis assulatus	-	-	-	-	x	-	x																	
Discorbis margaritiferus	-	-	-	-	x	-	x	-	x	-	-	-	x											
Dorothia parri	-	-	-	-	x	-	x	-	x	x	x	-	-	-	-	-	-	-	x					
Eponides scabriculus	-	-	-	-	x	-	x	-	-	-	x	-	-	-	-	x	x	-	-	-	x	-	-	x
Eponides sp. nov.	-	-	-	-	x	-	-	-	x															
Glabratella crassa	-	-	-	-	x	-	x	-	x															
Glabratella sp. 2	-	-	-	-	x																			
Globigerina cf. danvillensis	-	-	-	-	x																			
Globigerina cf. increbescens	-	-	-	-	x																			
Globigerina mexicana	-	-	-	-	x																			
Globigerina pseudobulloides	-	-	-	-	x	-	-	-	x															
Globigerina triloculinoides	-	-	-	-	x	-	x	-	x	x	-	x	x	-	-	-	-	-	-	-	x			
Globorotalia chapmani	-	-	-	-	x	-	x	-	x															
Globulina gibba	-	-	-	-	x																			
Heronallenia pulsilla	-	-	-	-	x	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	x			
Heronallenia sp. nov. (aff. lingulata)	-	-	-	-	x	-	x	x	x	x	-	x	x	-	-	x								
Lagena favosopunctata	-	-	-	-	x																			
Lagena globosa	-	-	-	-	x	-	x																	
Lagena hexagona	-	-	-	-	x	-	-	-	x	x	-	x												
Lagena laevigata var. globosa	-	-	-	-	x																			
Lagena marginata	-	-	-	-	x	-	-	-	x	-	-	x												
Lagena striata var. semiornata	-	-	-	-	x																			
Lagena sp. 1	-	-	-	-	x	-	x	-	x	-	-	x												
Lamarckina glenoensis	-	-	-	-	x	-	-	x																
Liebusella antipodum	-	-	-	-	x	-	x	-	x															
Massilina torquayensis	-	-	-	-	x	-	x																	
Sigmoilina chapmani	-	-	-	-	x	-	-	-	x															
Sphaeroidina bulloides	-	-	-	-	x	-	-	-	x	x	-	x	x											
Stomatorbina torrei	-	-	-	-	x	-	-	-	x															
Uvigerina hispida	-	-	-	-	x	-	x																	
Cassidulina armosa	-	-	-	-	-	x	-	x	x	-	-	x	-	-	-	x	-	-	-	-	x			
Bolivina elongata	-	-	-	-	-	-	x																	
Bolivinopsis crespinae	-	-	-	-	-	-	x																	
Cassidulina inconspicua	-	-	-	-	-	-	x																	
Cassidulina cf. moodyensis	-	-	-	-	-	-	x																	
Cornuspira crassisepta	-	-	-	-	-	-	x																	
Cyclammina incisa	-	-	-	-	-	-	x																	
Dentalina semicostata	-	-	-	-	-	-	x																	
Dentalina soluta	-	-	-	-	-	-	x	-	x	x	-	x	-	-	-	-	-	-	-	-	x			
Discorbinella sp. 1	-	-	-	-	-	-	x	-	x	-	-	-	-	-	-	-	-	-	-	-	x			
Elphidium cf. crespinae	-	-	-	-	-	-	x	x	x	x	-	-	-	-	-	-	x	-	-	-	x			
Frondicularia cf. lorifera	-	-	-	-	-	-	x	-	x	-	-	-	-	-	-	-	-	-	x	-	x			
Globigerina eocenica	-	-	-	-	-	-	x	-	x	-	-	-	-	-	-	-	-	-	-	-	x			
Globigerina ouachitaensis	-	-	-	-	-	-	x	-	x	-	-	-	-	-	-	-	-	-	-	-	x			
Globigerinella micra	-	-	-	-	-	-	x																	
Guttulina hantkeni	-	-	-	-	-	-	x	-	-	-	-	x	x											
Guttulina (Sigmoidina) silvestrii	-	-	-	-	-	-	x	x	x	-	-	x												
Gyroidina soldanii	-	-	-	-	-	-	x																	
Lagena apiculata	-	-	-	-	-	-	x																	
Lagena distoma	-	-	-	-	-	-	x																	
Lagena plumigera	-	-	-	-	-	-	x																	
Lagena semistriata	-	-	-	-	-	-	x																	
Marginulina costata	-	-	-	-	-	-	x	x																
Nonionella hantkeni	-	-	-	-	-	-	x																	
Notorotalia sp. 1	-	-	-	-	-	-	x	x	x	-	-	x	-	-	-	-	x							
Pseudoglandulina clarkei	-	-	-	-	-	-	x	-	x	x	-	x	x											
Pullenia quinqueloba	-	-	-	-	-	-	x	-	-	-	-	x	-	-	-	-	-	x	-	-	x			
Ramulina globulifera	-	-	-	-	-	-	x																	
Robulus alabamensis	-	-	-	-	-	-	x	-	-	-	-	x	-	-	-	-	-	-	-	-	x			
Robulus inornata	-	-	-	-	-	-	x																	
Rotalia sp. nov.	-	-	-	-	-	-	x																	
Rotorbinella finlayi	-	-	-	-	-	-	x	-	x															
Sigmoilina tenuis	-	-	-	-	-	-	x																	
Sigmomorphina vaughani	-	-	-	-	-	-	x	-	x	-	-	x												
Sphaeroidina variabilis	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	x			
Spirillina tuberculata	-	-	-	-	-	-	x																	
Triloculina trigonula	-	-	-	-	-	-	x																	
Triloculinella oblonga	-	-	-	-	-	-	x	-	x															
Anomalina westraliensis	-	-	-	-	-	-	-	x	-	x	-	-	-	-	-	-	-	-	-	-	x			
Cassidulina subglobosa var. horizontalis	-	-	-	-	-	-	-	x	x	x	-	x	-	x	x	x	x							
Cibicides vortex	-	-	-	-	-	-	-	x	x	-	x	x	x	x	x	x	x	x	x	x	x	x	x	
Dentalina cf. obliqua	-	-	-	-	-	-	-	x	-	x	-	x												
Eponides repandus var.	-	-	-	-	-	-	-	x																
Gaudryina (Pseudogaudryina) crespinae	-	-	-	-	-	-	-	x	x	-	-	x	-	-	-	-	-	-	x					
Glandulina ampulla	-	-	-	-	-	-	-	x																
Gypsina globulus	-	-	-	-	-	-	-	x	x	-	-	-	-	-	-	-	-	-	x					
Sherbornina atkinsoni	-	-	-	-	-	-	-	x	x	x	-	x	x	x	x	x	x	x	x					
Sigmomorphina cf. schencki	-	-	-	-	-	-	-	x																
Siphonina australis	-	-	-	-	-	-	-	x	x	x	-	x	x											
Valvulineria pauciloculata	-	-	-	-	-	-	-	x																
Victoriella plecte	-	-	-	-	-	-	-	x	x	-	-	x												
Alabamina tuberculata var. australiensis	-	-	-	-	-	-	-	-	x	-	-	x	-	-	-	-	x							
Anomalina ammonoides var. acuta	-	-	-	-	-	-	-	-	x	-	-	x	-	-	-	-	-	-	-	-	x			
Anomalina subnonionoides	-	-	-	-	-	-	-	-	x	x	-	x	x	x	x	x	-	x	x	-	x			
Bolivina hebes var. victoriensis	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	x			
Bolivina sp. 2	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	x			
Buliminella westraliensis	-	-	-	-	-	-	-	-	x															
Calcarina sp. nov. (aff. mackayi)	-	-	-	-	-	-	-	-	x	x	-	-	-	-	x	x	x	x	x	x	x	x	x	
Carpenteria rotaliformis	-	-	-	-	-	-	-	-	x															
Cassidulinoides chapmani	-	-	-	-	-	-	-	-	x	-	-	x	x											
Cornuspira byramensis	-	-	-	-	-	-	-	-	x															
Dentalina [illegible]	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	x			
Dentalina fissicostata	-	-	-	-	-	-	-	-	x															
Dimorphina janjukensis	-	-	-	-	-	-	-	-	x	-	-	x	x											
Discorbinella sp. 2	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	x			
Discorbinella sp. 3	-	-	-	-	-	-	-	-	x															
Dorothia subglabra	-	-	-	-	-	-	-	-	x	-	-	x												
Elphidium sp. nov.	-	-	-	-	-	-	-	-	x	x	-	x												
Frondicularia victoriae	-	-	-	-	-	-	-	-	x															
Gaudryina collinsi	-	-	-	-	-	-	-	-	x															
Glabratella petalifera	-	-	-	-	-	-	-	-	x															
Guttulina caudata	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	x			
Guttulina jarvisi	-	-	-	-	-	-	-	-	x	-	-	x												
Guttulina problema	-	-	-	-	-	-	-	-	x	-														
Gyroidina scrobiculata	-	-	-	-	-	-	-	-	x	-	-	x	-	-	-	-	x							
Heronallenia vicksburgensis	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	x								
Lagena flexa	-	-	-	-	-	-	-	-	x	-														
Lagena laevis	-	-	-	-	-	-	-	-	x	-	-	x												
Lagena sulcata	-	-	-	-	-	-	-	-	x															
Patellina cf. corrugata	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	x					
Polystomellina sp. nov.	-	-	-	-	-	-	-	-	x	-														
Pyrgo depressa	-	-	-	-	-	-	-	-	x															
Quinqueloculina lamarckiana	-	-	-	-	-	-	-	-	x															
Quinqueloculina cf. mauricensis	-	-	-	-	-	-	-	-	x	x														
Quinqueloculina schreiberiana	-	-	-	-	-	-	-	-	x															
Quinqueloculina cf. whitei	-	-	-	-	-	-	-	-	x															
Robertina ovigera	-	-	-	-	-	-	-	-	x															
Sigmoidella bortonica	-	-	-	-	-	-	-	-	x	x	-	x	-	-	-	x								
Sigmoidella plummerae	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	x								
Sigmoilina victoriensis	-	-	-	-	-	-	-	-	x															
Spiroloculina canaliculata	-	-	-	-	-	-	-	-	x															
Spirillina decorata	-	-	-	-	-	-	-	-	x															
Triloculina tricarinata	-	-	-	-	-	-	-	-	x															
Vaginulina sp. nov.	-	-	-	-	-	-	-	-	x															
Guttulina spicaeformis	-	-	-	-	-	-	-	-	-	x														
Planorbulina macphersoni	-	-	-	-	-	-	-	-	-	x	-	x	x	x	x	x	x	x	x	x	x			
Bitubulogenerina cf. howei	-	-	-	-	-	-	-	-	-	-	-	x												
Bulimina pupula	-	-	-	-	-	-	-	-	-	-	-	x	x											
Elphidium pseudoinflatum	-	-	-	-	-	-	-	-	-	-	-	x	x	x	x	-	x	-	x					
Nodosaria cocoaensis	-	-	-	-	-	-	-	-	-	-	-	x												
Pseudopolymorphina dosnei	-	-	-	-	-	-	-	-	-	-	-	x												
Pullenia bulloides	-	-	-	-	-	-	-	-	-	-	-	x												
Pullenia eocenica	-	-	-	-	-	-	-	-	-	-	-	x												
Robulus alato-limbosus	-	-	-	-	-	-	-	-	-	-	-	x												
Amphistegina sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	x	x	x	-	x			
Guttulina irregularis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	x			
Notorotalia sp. 2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x									
Stomatorbina sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x									
Elphidium cf. chapmani	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x								
Pseudopolymorphina rutila var. parri	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x								
Calcarina verriculata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	x	-	-	-	x	
Operculina sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x						
Angulogerina cf. cooperensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x			
Angulogerina sp. 9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x			
Nonion sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x			

TABLE VI

Foraminifera	RP 1	RP 2	RP 3	RP 4	RP 5	RP 6	RP 7	RP 8
Amphistegina sp.	x	x	-	x	-	-	-	-
Anomalina subnonionoides	x	x	x	x	x	x		
Calcarina sp. aff. mackayi	x	x	x	x				
Calcarina cf. verriculata	x	x	-	x				
Cassidulina subglobosa var. horizontalis	x	-	x	x	-	x		
Cibicides vortex	x	-	x	x				
Cibicides sp. 1	x	x	x	x	x	x	x	x
Gypsina globulus	x							
Sherbornina atkinsoni	x	-	x					
Alabamina tenuimarginata	-	x						
Alabamina tuberculata var. australiensis	-	x						
Angulogerina vicksburgensis	-	x	-	-	-	x		
Angulogerina sp. 2	-	x	-	-	-	x		
Anomalina ammonoides var. acuta	-	x	-	-	x	x		
Anomalina perthensis	-	x	x	-	x	x		
Bolivina cf. antiqua	-	x						
Bolivina aff. jacksonensis	-	x						
Bolivina scalprata var. retiformis	-	x						
Bolivina victoriana	-	x	-	-	-	x		
Bolivina sp. 2	-	x	-	-	-	x		
Carpenteria sp.	-	x						
Cassidulina armosa	-	x						
Cassidulina inconspicua	-	x						
Cassidulinoides chapmani	-	x	x					
Cibicides lobatulus	-	x	-	x				
Cibicides umbonifer	-	x						
Dimorphina janjukensis	-	x						
Discorbis bertheloti var. nov.	-	x	-	x	x	x	x	
Discorbis margaritiferus	-	x						
Genus aff. Eoannularia	-	x	x	x				
Eponides repandus var.	-	x	-	x	x	-	x	
Eponides scabriculus	-	x	-	-	-	x	-	x
Frondicularia victoriae	-	x						
Gaudryina (Pseudogaudryina) crespinae	-	x	x	x				
Globigerina pseudobulloides	-	x	-	-	-	x		
Globigerina triloculinoides	-	x	-	-	-	x		
Globigerina sp.	-	x						
Guttulina irregularis	-	x	x					
Guttulina spicaeformis	-	x						
Guttulina (Sigmoidina) silvestrii	-	x	x	x	-	x		
Gyroidina scrobiculata	-	x	x					
Heronallenia vicksburgensis	-	x						
Heronallenia sp. nov. aff. lingulata	-	x						
Lagena favosopunctata	-	x						
Lagena cf. grinzingensis	-	x						
Lagena hexagona	-	x						
Lagena laevis	-	x	-	-	-	x		
Nodosaria radicula	-	x						
Nonionella hantkeni	-	x						
Notorotalia sp. 1	-	x	x	-	-	-	x	
Pseudoglandulina clarkei	-	x	-	x	-	x		
Pullenia quinqueloba	-	x						
Reophax sp.	-	x						
Rotorbinella finlayi	-	x						
Sigmoidella bortonica	-	x	x	x	x	x	x	
Sigmoidella plummerae	-	x	-	x				
Sigmomorphina vaughani	-	x						
Sphaeroidina bulloides	-	x	-	-	-	x		
Stomatorbina torrei	-	x	-	x				
Vaginulina sp. 1	-	x						
Valvulineria paucilocula	-	x	-	-	-	x		
Bolivina nobilis	-	-	x					
Dentalina cf. obliqua	-	-	x	-	x	x	x	
Guttulina hantkeni	-	-	x					
Marginulina cf. cooperensis	-	-	x					
Pseudopolymorphina tasmanica	-	-	x					
Anomalina sp. nov.	-	-	-	x				
Dentalina soluta	-	-	-	x	-	x		
Dentalina subcostata	-	-	-	x				
Dorothia parri	-	-	-	x	x	x		
Elphidium pseudoinflatum	-	-	-	x				
Frondicularia sp.	-	-	-	x				
Gaudryina (Siphogaudryina) victoriana	-	-	-	x				
Planorbulina macphersoni	-	-	-	x				
Pseudopolymorphina rutila var. parri	-	-	-	x				
Quinqueloculina cf. mauricensis	-	-	-	x				
Quinqueloculina schrieberiana	-	-	-	x				
Quinqueloculina vulgaris	-	-	-	x				
Clavulinoides szaboi var. victoriensis	-	-	-	x	x	x	x	
Cornuspira byramensis	-	-	-	-	x	x	x	
Cornuspira crassisepta	-	-	-	-	x			
Dentalina semistriata	-	-	-	-	x			
Lagena scarenaensis var. glabra	-	-	-	-	x	x		
Nodosaria latejugata	-	-	-	-	x			
Robulus cf. knighti	-	-	-	-	x			
Spiroplectammina mississippiensis var. alabamensis	-	-	-	-	x			
Triloculina tricarinata	-	-	-	-	x	x	x	
Astrononion cf. australe	-	-	-	-	-	x		
Bolivina crenulata	-	-	-	-	-	x		
Cibicides sp. 2	-	-	-	-	-	x		
Enantiodentalina communis	-	-	-	-	-	x		
Globorotalia chapmani	-	-	-	-	-	x		
Lagena apiculata	-	-	-	-	-	x		
Lagena marginata	-	-	-	-	-	x		
Nodosaria pyrulata	-	-	-	-	-	x		
Robulus alabamensis	-	-	-	-	-	x		
Siphonina australis	-	-	-	-	-	x		
Uvigerina hispida	-	-	-	-	-	x		
Dentalina fissicostata	-	-	-	-	-	-	x	x
Textularia abbreviata	-	-	-	-	-	-	x	
Pyrgo depressa	-	-	-	-	-	-	-	x

TABLE VII

Foraminifera	BR 18	BR 17	BR 14	BR 5	BR 4	BR 3	BR 2	BR 1	BR 6	BR 7	BR 8	BR 9	BR 10	BR 11	BR 12	BR 13
Alabamina tenuimarginata var.	x	x	–	x												
Amphistegina sp.	x	x	x	x												
Angulogerina subangularis	x	x	–	x												
Angulogerina sp. 2	x	x	x	x												
Anomalina ammonoides var. acuta	x	x	x	x	x	–	–	x	–	–	x					
Anomalina perthensis	x	x	x	x	–	–	x	–	–	–	x					
Anomalina subnonionoides	x	x	x	x	x	–	x	–	–	–	–	–	–	x	x	
Baggatella sp. nov.	x															
Bolivina scalprata var. retiformis	x	x														
Bolivina victoriana	x	x	x	x												
Bolivina sp. 1 (aff. B. spiralis)	x	x	–	x												
Bolivina sp. 2	x	–	x													
Bolivinella subpectinata var. nov.	x	–	–	x												
Bulimina pupula	x	x														
Buliminella madagascarensis var. spicata	x	–	–	x	–	–	–	–	–	–	x					
Calcarina sp. nov. (aff. C. Mackayi)	x	x	x	x												
Carpenteria rotaliformis	x															
Cassidulinoides chapmani	x	x	–	x												
Ceratobulimina westraliensis	x	x	–	x												
Cibicides pseudoconvexus	x	–	–	x												
Cibicides umbonifer	x	x	–	x												
Cibicides vortex	x	x	x	x												
Cibicides sp. 1	x	x	x	x	x	x	–	x	–	–	x					
Clavulinoides szaboi var. victoriensis	x	x	x	x	–	–	x	x	–	–	x	x	x	x		
Cornuspira byramensis	x	x	x	x	x											
Cornuspira crassisepta	x	x	x	x	x	–	x	–	–	–	x					
Dentalina fissicostata	x	–	x	x	x											
Dentalina semicostata	x	–	–	–	–	–	–	–	–	–	–	x	–	x		
Dentalina subcostata	x	x	x	x	–	–	–	x	–	–	–	x	x	x		
Dimorphina janjukensis	x	–	–	x												
Discorbis bertheloti var. nov.	x	x	x	x	–	–	x	x								
Discorbis margaritiferus	x	–	–	x												
Discorbis sp.	x	x	x	–	x											
Epistomina eocenica	x	–	–	x												
Eponides repandus var.	x	–	x	–	–	–	–	–	–	–	x					
Eponides sp. nov.	x	x	x													
Gaudryina (Pseudogaudryina) crespinae	x	x	x	x												
Glabratella crassa	x	x	–	x	–	–	–	–	–	–	x					
Glabratella petalifera	x	x	–	x												
Globigerina ouachitensis	x	–	x	x	x	–	–	–	–	–	x					
Globigerina pseudobulloides	x	–	x	–	–	–	–	–	–	–	x					
Globigerina triloculinoides	x	–	x	x	x	–	–	–	–	–	x	x				
Globulina gibba	x	x	x	x	–	–	–	–	–	–	–	–	–	x		
Globorotalia chapmani	x	x	–	x	–	–	–	–	–	–	x					
Guttulina jarvisi	x															
Guttulina (Sigmoidina) silvestrii	x	–	x	–	–	–	–	–	–	–	–	–	–	x		
Gyroidina scrobiculata	x	x	x	x	x											
Heronallenia vicksburgensis	x															
Hopkinsina bortotara	x															
Karreriella siphonella	x	x	x	x												
Lagena favosopunctata	x	x	x	x	x	–	–	–	–	–	x					
Lagena globosa	x	–	–	–	–	–	–	–	–	–	x					
Lagena hexagona	x	–	x	x												
Lagena cf. lunata	x	x														
Lagena marginata	x	x	–	x	–	–	–	–	–	–	x					
Lagena selseyensis	x	x	–	x												
Lagena scarenaensis var. glabrata	x	x	–	x	–	–	–	–	–	–	x	–	x			
Lagena sulcata	x	x	x	x												
Lagena sp. 1	x	x	–	x	–	–	–	–	–	–	x					
Lagena sp. 3	x															
Lagena sp. 4	x															
Lamarckina glencoensis	x	x	x	x	–	–	–	–	–	–	x					
Liebusella antipodum	x	x	x	–	–	–	–	x								
Listerella victoriensis	x															
Massilina torquayensis	x	x	x	x												
Nonionella hantkeni	x	x	–	x												
Patellina cf. corrugata	x	x	–	x												
Planularia tricarinella	x															
Pseudoglandulina clarkei	x	x	x	x	x	–	x	–	–	–	x					
Pseudopolymorphina cf. decora	x															
Pullenia cf. jarvisi	x															
Pullenia quinqueloba	x	x	x	x	–	–	x	–	–	–	x	x				
Pyrgo ringens	x															
Pyrgo sarsi	x	–	–	x	x											
Quinqueloculina ornithopetra	x	x	x	x												
Quinqueloculina schreiberiana	x	x	x	x												
Quinqueloculina singletoni	x	x	x	x												
Quinqueloculina venusta	x	–	–	x												
Quinqueloculina cf. vulgaris	x	–	x	x	x	–	x									
Rotorbinella finlayi	x	x	–	x												
Sigmoidella tortonica	x	–	x	x												
Sigmoilina chapmani	x	x	x	x	–	–	–	–	–	–	x					
Sigmoilina victoriensis	x	x	x	x		–	–	–	–	–	x					
Sigmomorphina vaughani	x	x	–	x												
Siphonina australis	x	x	x	x	–	–	–	–	–	–	x	x	–	x		
Sphaeroidina variabilis	x	x	x	x												
Spirillina decorata	x	–	–	–	x	x	x	x	–	–	x					
Spirillina tuberculata	x	–	–	–	–	–	–	–	–	–	x					
Spirillina sp. nov.	x															
Stomatorbina torrei	x	x	x	x	–	–	–	–	–	–	x					
Triloculina tricarinata	x	x	x	x	–	x	x									
Ammobaculites reophaciformis	–	x	–	–	–	–	–	–	–	–	–	x				
Astrononion australe	–	x	–	x	–	–	–	–	–	–	–	x				
Bolivina fastigia	–	x	–	–	x	x										
Bolivina cf. nobilis	–	x														
Bolivina cf. plicatella	–	x														
Bulimina tarda	–	x														
Buliminella obtusata	–	x														
Cassidulina armosa	–	x	–	x												
Cassidulina subglobosa var. horizontalis	–	x	x	x												
Cassidulina sp.	–	x														
Cibicides perlucida	–	x	–	x	–	–	–	–	–	–	x	x				
Cibicides ungerianus	–	x														
Cornuspira foliacea	–	x	–	x												
Dentalina soluta	–	x	x	x	–	x	x	x	–	–	x	–	–	x		
Dentalina sp. nov.	–	x														
Dorothia parri	–	x	x	x	x	x	x	x	–		x	–	–	x		
Eponides scabriculus	–	x	x	x	–	–	–	–	–	–	–	–	x			
Gaudryina collinsi	–	x	x	x	–	–	–	–	–	–	–	–	–	x		
Gaudryina (Pseudogaudryina) sp. nov.	–	x	–	x												
Globigerina cf. dissimilis	–	x	–	x	–	–	–	–	–	–	–	–	–	x		
Globigerina eocena	–	x														
Guembelina cf. goodwini	–	x														
Guttulina irregularis	–	x	x	x												
Hauerina tateana	–	x	–	x												
Heronallenia sp. nov.	–	x														
Lagena elongata	–	x														
Lagena perthensis	–	x	–	x												
Lagena sp. 5	–	x														
Nodosaria hispida	–	x	–	x												
Nodosaria longiscata	–	x	–	x												
Nodosaria sp.	–	x														
Plectofrondicularia sp. nov.	–	x														
cf. Pseudobulimina glaessneri	–	x														
Pyrgo depressa	–	x	x	x												
Quinqueloculina lamarckiana	–	x	x	x	x	x	x	–	–	–	x					
Quinqueloculina cf. mauricensis	–	x	x	x												
Quinqueloculina seminulum	–	x														
Quinqueloculina cf. whitei	–	x	x													
Reussella pulchra	–	x	x													
Rotalia sp. nov.	–	x														
Sigmomorphina sp.	–	x														
Sphaeroidina bulloides	–	x	x	x	–	–	x	–	–	–	x	–	–	–	x	
Spiroloculina disparilis	–	x	–	x												
Spiroloculina sp.	–	x														
Spiroplectammina cf. wilcoxensis	–	x														
Textularia aff. lalickeri	–	x														
Textularia cf. pectinata	–	x														
Textularia siphonifera	–	x	x	x												
Triloculinella oblonga	–	x	x													
Vaginulina legumen	–	x														
Vaginulina sp. 1	–	x														
Victoriella plecte	–	x	x	x												
Virgulina schreibersiana	–	x														
Cibicides perforatus var. notocenicus	–	–	x													
Dentalina jacksonensis	–	–	x	x	–	–	–	–	–	–	x					
Dentalina mucronata	–	–	x													
Dentalina sp. 1	–	–	x													
Dorothia subglabra	–	–	x													
Guttulina caudata	–	–	x	x	x											
Guttulina hantkeni	–	–	x													
Guttulina spicaeformis	–	–	x	x												
Gypsina globulus	–	–	x													
Lagena laevigata	–	–	x	x												
Lagena striata	–	–	x	–	–	–	–	–	–	–	x					
Nodosaria vertebralis	–	–	x													
Pseudopolymorphina sp. nov.	–	–	x	x												
Pullenia bulloides	–	–	x													
Pyrgo aff. affinis	–	–	x													
Pyrgo bulloides	–	–	x													
Robulus alabamensis	–	–	x													
Sigmoilina asperula	–	–	x													
Sigmomorphina cf. trinitatensis	–	–	x	x												
Triloculina trigonula	–	–	x	x	x	x										
Tubulogenerina vicksburgensis	–	–	x	x												
Alabamina obtusa var. westraliensis	–	–	–	x												
Alabamina tuberculata var. australiensis	–	–	–	x												
Allomorphina cf. trigona var. obtusa	–	–	–	x												
Angulogerina aff. rugiplicata	–	–	–	x												
Angulogerina australe	–	–	–	x												
Annulopatellina sp. nov.	–	–	–	x												
Articulina cf. advena	–	–	–	x												
Articulina cf. victoriana	–	–	–	x												
Bolivina cf. byramensis	–	–	–	x												
Bolivina cf. gardneri	–	–	–	x												
Bolivina cf. mississippiensis var. costifera	–	–	–	x												
Bolivina cf. peruviana	–	–	–	x												
Bolivina sublobata	–	–	–	x												
Bolivinella compressa	–	–	–	x												
Bolivinopsis crespinae	–	–	–	x												
Buliminella westraliensis	–	–	–	x												
Cassidulina globosa	–	–	–	x												
Cassidulina subglobosa	–	–	–	x												
Ceratobulimina cf. lornensis	–	–	–	x												
Crespinella sp.	–	–	–	x												
Cyclammina sp.	–	–	–	x	x											
Cycloloculina sp.	–	–	–	x												
Dentalina cooperensis var. gracilescata	–	–	–	x												
Discorbis assulatus	–	–	–	x	x											
Discorbis cf. bulla	–	–	–	x												
Discorbis cf. huneri	–	–	–	x												
Discorbinella sp. 1	–	–	–	x												
Ellipsonodosaria cocoaensis	–	–	–	x												
Globigerina eocenica	–	–	–	x												
Globigerina mexicana	–	–	–	x												
Globigerinoides index	–	–	–	x												
Globorotalia sp. nov.	–	–	–	x												
Globulina minuta	–	–	–	x												
Guembelina mulitcellaris	–	–	–	x												
Guembelina venezuelana var. rugosa	–	–	–	x												
Gyroidina soldanii var. octocamerata	–	–	–	x												
Hantkenina alabamensis subsp. compressa	–	–	–	x												
Hauerina sp. nov.	–	–	–	x												
Lagena apiculata	–	–	–	x												
Lagena curvi-costata	–	–	–	x												
Lagena distoma	–	–	–	x												
Lagena gracillima	–	–	–	x												
Lagena orbignyana cf. var. crenulata	–	–	–	x												
Lagena orbignyana var. stellata	–	–	–	x												
Lagena orbignyana cf. var. trinitatensis	–	–	–	x												
Lagena quadrata	–	–	–	x												
Lagena tenuis var.	–	–	–	x												
Lenticulina convergens	–	–	–	x												
Loxostomum cf. limbatum	–	–	–	x												
Loxostomum wilcoxensis	–	–	–	x												
Marginulina cf. gladius	–	–	–	x												
Nodosaria pyrula	–	–	–	x												
Nodosaria raphanus	–	–	–	x												
Nonionella cf. zenitans	–	–	–	x												
Pullenia reussi	–	–	–	x												
Pyrgo anomala	–	–	–	x												
Pyrgo elongata	–	–	–	x												
Reophax sp.	–	–	–	x												
Reussella cf. oberburgensis	–	–	–	x												
Robertina wilcoxensis	–	–	–	x												
Robertina ovigera	–	–	–	x												
Robulus limbosus	–	–	–	x												
Robulus arcuato-striatus	–	–	–	x												
Sherbornina atkinsoni	–	–	–	x												
Sigmoilina schlumbergeri	–	–	–	x												
Sigmoilina tenuis	–	–	–	x												
Spiroplectammina mississippiensis	–	–	–	x												
Vaginulina schwageri	–	–	–	x												
Vaginulinopsis gippslandicus	–	–	–	x												
Virgulina dibollensis	–	–	–	x												
Cyclammina incisa	–	–	–	–	x											
Spiroloculina canaliculata	–	–	–	–	x	–	x	–	–	–	x					
Alabamina sp. nov.	–	–	–	–	–	–	–	–	–	–	x					
Anomalina cf. macroglabra	–	–	–	–	–	–	–	–	–	–	x					
Anomalina cf. pinguiglabra	–	–	–	–	–	–	–	–	–	–	x					
Cibicides sp. 3	–	–	–	–	–	–	–	–	–	–	x					
Lagena hispida	–	–	–	–	–	–	–	–	–	–	x					
Lagena mississippiensis	–	–	–	–	–	–	–	–	–	–	x					
Lagena orbignyana var. pileata	–	–	–	–	–	–	–	–	–	–	x					
Lagena wallacei	–	–	–	–	–	–	–	–	–	–	x					
Reussella spinulosa	–	–	–	–	–	–	–	–	–	–	x					
Calcarina cf. verriculata	–	–	–	–	–	–	–	–	–	–	–	x				
Cibicides cf. perlucida	–	–	–	–	–	–	–	–	–	–	–	x				
Cibicides victoriensis	–	–	–	–	–	–	–	–	–	–	–	x	–	x	x	
Globigerinoides trilobus	–	–	–	–	–	–	–	–	–	–	–	x				
Globulina inaequalis	–	–	–	–	–	–	–	–	–	–	–	x	–	–	x	
Marginulina aff. moodyensis	–	–	–	–	–	–	–	–	–	–	–	x				
Planulina cf. mexicana	–	–	–	–	–	–	–	–	–	–	–	x				
Pyrulina thouini	–	–	–	–	–	–	–	–	–	–	–	x				
Robulus cf. inornatus	–	–	–	–	–	–	–	–	–	–	–	x	–	–	x	
Glandulina laevigata	–	–	–	–	–	–	–	–	–	–	–	–	x			
Globigerina trilocularis	–	–	–	–	–	–	–	–	–	–	–	–	x			
Guttulina problema	–	–	–	–	–	–	–	–	–	–	–	–	x			
Robulus articulatus	–	–	–	–	–	–	–	–	–	–	–	–	x	x		
Dentalina sp. 2	–	–	–	–	–	–	–	–	–	–	–	–	–	x		
Guttulina regina	–	–	–	–	–	–	–	–	–	–	–	–	–	x	x	
Operculina victoriensis	–	–	–	–	–	–	–	–	–	–	–	–	–	x		
Pyrulina fusiformis	–	–	–	–	–	–	–	–	–	–	–	–	–	x		
Robulus cf. cultratus var. antipodum	–	–	–	–	–	–	–	–	–	–	–	–	–	x		
Robulus nigriseptus	–	–	–	–	–	–	–	–	–	–	–	–	–	x	x	
Nodosaria cf. raphanus	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	
Robulus aff. articulatus	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	

Table VIII

Foraminifera	BR. 19	BR. 20	BR. 21	BR. 22	BR. 23	BR. 24	BR. 25
cf. Ammodiscus	x	x	–	–	–	x	
Anomalina cf. pinguiglabra	x						
Cibicides cf. ungerianus	x						
Cibicides sp. 2							
Clavulinoides szaboi var. victoriensis	x	x					
Dentalina obliqua	x						
Dentalina soluta	x	x					
Dentalina subcostata	x	x					
Discorbis sp. 1	x						
Dorothia parri	x	x					
Eponides scabriculus	x						
Gaudryina collinsi	x						
Globigerinoides trilobus	x	x	–	–	x		
Nodosaria raphanus	x	x					
Notorotalia sp. 1	x	x					
Robulus cf. nigriseptus	x	–					
Anomalina subnonionoides	–	x					
Astrononion australe	–	x					
Bolivina cf. antiqua	–	x					
Bolivina arta	–	x					
Bolivina scalprata var. retiformis	–	x					
Cassidulina subglobosa	–	x					
Cibicides sorrentae	–	x					
Planulina wuellerstorfi	–	x					
Siphonina australis	–	x					
Textularia sagittula	–	x	x				
Crespinella umbonifera	–	–	x	–	–	x	
Calcarina cf. verriculata	–	–	–	x	–	–	x
Cibicides cf. umbonifer	–	–	–	–	–	x	
Cyclammina sp.	–	–	–	–	–	x	
Pyrgoella sphaera	–	–	–	–	–	x	
Robulus articulata	–	–	–	–	–	x	

Table IX

Foraminifera	FB. 1& A.	FB. 2	FB. 3	FB. 4	FB. 5
Angulogerina australis	x				
Angulogerina sp. 1	x				
Anomalina perthensis	x	x	x	x	x
Anomalina subnonionoides	x	x	x	x	x
Astrononion australe	x	–	x		
Bolivina fastigia	x	–	x		
Bolivina victoriana	x	x	x		
Bolivina sp. 1 (aff. B.spiralis)	x				
Bolivina sp. 2	x				
Bolivinella subpectinata var. nov.	x				
Bolivinopsis crespinae	x	x	x		
Bulimina pupula	x				
Buliminella pupa	x	x	x		
Buliminella westraliensis	x	–	x		
Calcarina sp. nov. (aff. C.mackayi)	x	x	x	x	x
Cassidulina armosa	x	x	x		
Cassidulina subglobosa var. horizontalis	x	–	–	x	x
Cassidulinoides chapmani	x	x	x		
Ceratobulimina westraliensis	x	x	–	x	
Cibicides pseudoconvexus	x	x	–	–	x
Cibicides umbonifer	x	x	x		
Cibicides vortex	x	x	x		
Cibicides sp. 1	x	x	x		
Cornuspira byramensis	x	x	–	x	
Cornuspira crassisepta	x	x	x	x	x
Cornuspira foliacea	x				
Cyclammina rotundata	x				
Dentalina fissicostata	x	x	x		
Dentalina subcostata	x	x			
Dentalina soluta	x	x	x	–	x
Dimorphina janjukensis	x	x	x	x	
Discorbis assulatus	x	–	x		
Discorbis margaritiferus	x	x	x		
Discorbis sp. nov.	x				
Discorbinella sp. 1 (aff. D.biconcava)	x				
Discorbinella sp. 2	x	–	x		
Dorothia parri	x	x	x	x	x
Dorothia subglabra	x	–	x		
Eponides repandus var.	x	x	–	–	x
Frondicularia victoriae	x	x	–	x	–
Gaudryina collinsi	x	x	–	–	x
Gaudryina (Pseudogaudryina) crespinae	x	x	–	–	x
Glabratella crassa	x	–	x		
Glabratella cf. globigeriniformis	x				
Glabratella cf. petalifera	x	x	x		
Glabratella sp.nov.	x	x	x		
Globigerina pseudobulloides	x	x	x		
Globigerina triloculinoides	x	x	x		
Globorotalia chapmani	x	x	x		
Guttulina hantkeni	x	x	–	x	
Guttulina irregularis	x	–	x	x	
Gypsina globulus	x	–	x	x	x
Gyroidina scrobriculata	x	x	–	–	x
Gyroidina soldanii	x				
Karreriella siphonella	x				
Lagena orbignyana var. stellata	x	–	x		
Lagena scarenaensis var. glabrata	x				
Lagena selseyensis	x	x	x		
Lamarckina glencoensis	x	–	x	x	
Massilina torquayensis	x	x	x	x	x
Patellina cf. corrugata	x	x	x		
Planorbulina macphersoni	x	–	x	x	
Pseudoglandulina clarkei	x	x			
Pseudopolymorphina cf. leopolitana	x				
Pyrgo depressa	x	x	–	x	–
Pyrgo laevis	x				
Pyrgoella sphaera	x	x	x	x	x
Pyrulina fusiformis	x				
Pyrulina sp.nov.	x				
Quinqueloculina lamarckiana	x	–	x		
Quinqueloculina cf. mauricensis	x	–	x		
Quinqueloculina schreiberiana	x	x	x	x	x
Quinqueloculina cf. whitei	x	x	–	x	x
Quinqueloculina venusta	x	–	x		
Quinqueloculina vulgaris	x	–	x		
Reussella cf. decorata	x				
Robulus cf. turbinatus	x				
Rotorbinella finlayi	x	x	x		
Sherbornina atkinsoni	x	–	x	x	x
Sigmoilina chapmani	x	–	x		
Sigmoilina victoriensis	x	x	x	x	
Sigmomorphina vaughani	x	–	x	x	
Siphonina australis	x	x	x		
Sphaeroidina bulloides	x	–	x		
Spirillina decorata	x	–	x	x	
Spiroloculina canaliculata	x				
Stomatorbina torrei	x	x	x	x	x
Textularia siphonifera	x	–	x		
Triloculina tricarinata	x	x	x	x	
Triloculina trigonula	x	x	x	x	
Triloculinella oblonga	x	x	–	x	
Uvigerina hispida	x	x			
Vaginulina cf. loeblichi	x	–	x		
Ammobaculites reophaciformis	–	x			
Amphistegina sp.	–	x			
Angulogerina sp. 3	–	x			
Bolivina jacksonensis	–	x	x		
Bolivina sublobata	–	x	x		
Bolivina sp.nov. (aff. crenulata)	–	x	x		
Dentalina subcostata	–	x	–	x	
Eponides sp. nov.	–	x	x	x	x
Globulina gibba	–	x			
Guttulina spicaeformis	–	x	x		
Lagena striata	–	x	x		
Lagena sp. 2	–	x	x		
Lagena sp. 3	–	x			
Pseudopolymorphina cf. doanei	–	x			
Pullenia quinqueloba	–	x	–	x	
Quinqueloculina seminulum	–	x	x	x	
Sigmoidella bortonica	–	x	x	–	x
Sigmomorphina schencki	–	x			
Sigmomorphina sp. 1	–	x			
Sigmomorphina sp. 2	–	x			
Sphaeroidina variabilis	–	x			
Spirillina tuberculata	–	x	x	x	x
Vaginulina legumen	–	x			
Alabamina tuberculata var. australiensis	–	–	x		
Angulogerina cf. elliptica	–	–	x		
Angulogerina sp. 2	–	–	x		
Annulopatellina sp. nov.	–	–	x		
Anomalina grosserugosa	–	–	x		
Baggatella sp.	–	–	x		
Bolivina crespinae	–	–	x		
Cassidulina inconspicua	–	–	x		
Cassidulina oblonga	–	–	x		
Cassidulinoides cf. howei	–	–	x		
Ceratobulimina dehiscens	–	–	x		
Ceratobulimina westraliensis	–	–	x		
Ceratobulimina sp. nov.	–	–	x		
Cibicides lobatulus	–	–	x	x	
Cibicides perforatus var. notocenicus	–	–	x	x	x
Cibicides sp. 2	–	–	x	x	
Eponides scabriculus	–	–	x	x	x
Globigerina cf. dissimilis	–	–	x		
Globigerina mexicana	–	–	x		
Globigerina cf. ouachitaensis	–	–	x		
Heronallenia pulsilla	–	–	x		
Heronallenia sp.	–	–	x		
Lagena favosopunctata	–	–	x		
Lagena flexa	–	–	x		
Lagena grocillicostata	–	–	x		
Lagena grinzingensis	–	–	x		
Lagena hexagona	–	–	x		
Lagena marginata	–	–	x		
Lagena pulcherrima	–	–	x		
Lagena scarenaensis var. glabrata	–	–	x		
Lagena semimarginata	–	–	x		
Lagena semistriata	–	–	x		
Lagena spiralis var. cubensis	–	–	x		
Lagena cf. watsonae	–	–	x		
Lamarckina cf. haliotis	–	–	x		
Nodosaria pyrula	–	–	x		
Nonionella hantkeni	–	–	x		
Pseudopolymorphina subnodosa	–	–	x		
Pyrulina crespinae	–	–	x		
Quinqueloculina ornithopetra	–	–	x	x	
Reussella pulchra	–	–	x		
Robulus alabamensis	–	–	x		
Sigmomorphina semitecta var. terquemiana	–	–	x		
Sigmomorphina williamsoni	–	–	–	x	
Sigmomorphina haeusleri	–	–	–	x	
Spiroloculina antillarum	–	–	–	x	
Elphidium pseudoinflatum	–	–	–	x	x
Guttulina caudata	–	–	–	x	
Notorotalia sp.nov. (aff. tainuia)	–	–	–	x	x
Quinqueloculina sp.nov.	–	–	–	x	x
Sigmomorphina jacksonensis	–	–	–	–	x
Spiroplectammina sp.	–	–	–	–	x

Table X

FORAMINIFERA	FS. 11	FS. 10	FS. 9	FS. 8	FS. 7	FS. 6	FS. 5	FS. 4	FS. 3	FS. 2	FS. 1
Amphistegina sp.	x	x									
Calcarina sp. nov. cf. mackayi	x	x	x	x							
Cassidulina subglobosa var. horizontalis	x	x	-	x							
Cibicides sp. 1	x	x	-	x	-	x	x	x	x		
Dentalina obliqua	x										
Gaudryina collinsi	x	x	x	x	x						
Gaudryina (Pseudogaudryina) crespinae	x	x									
Guttulina sp.	x										
Planorbulina macphersoni	x										
Quinqueloculina cf. mauricensis	x	x	x	x							
Quinqueloculina schreiberiana	x										
Rotorbinella finlayi	x										
Sherbornina atkinsoni	x										
Sigmoidella bortonica	x	x	x								
Sigmoilina victoriana	x										
Spirillina tuberculata	x	x									
Stomatorbina torrei	x	x	x								
Textularia sagittula	x										
Textularia siphonifera	x										
Victoriella plecte	x	x	x								
Alabamina tuberculata var. australiensis	-	x									
Angulogerina australe	-	x									
Anomalina ammonoides var. acuta	-	x	x	-	-	x	-	x	x		
Anomalina perthensis	-	x	x	x							
Anomalina subnonionoides	-	x	x	x	x	x					
Bolivina fastigia	-	x									
Bolivina cf. danvillensis	-	x									
Bolivina jacksonensis	-	x	-	-	-	-	-	-	x		
Bolivina scalprata var. retiformis	-	x									
Bolivina sublobata	-	x									
Bolivina victoriana	-	x									
Bolivina sp. 1	-	x									
Bolivinella subspectinata var. nov.	-	x									
Bulimina pupula	-	x									
Buliminella madagascarensis var. spicata	-	x									
Buliminella westraliensis	-	x									
Cassidulina alabamensis	-	x									
Cassidulina armosa	-	x									
Cassidulinoides chapmani	-	x									
Ceratobulimina cf. westraliensis	-	x									
Cibicides perforatus var. notocenicus	-	x									
Cibicides pseudoconvexus	-	x									
Cibicides umbonifer	-	x	x								
Cibicides vortex	-	x	x								
Clavulinoides szaboi var. victoriensis	-	x	x	x	-	-	x	x	x		
Cornuspira byramensis	-	x	-	-	x						
Cornuspira striolata	-	x									
Cyclammina incisa	-	x									
Dentalina fissicostata	-	x	x								
Dentalina soluta	-	x									
Dentalina subcostata	-	x	-	-	-	x	x	x	x		
Dimorphina janjukensis	-	x									
Discorbis sp. nov.	-	x									
Dorothia parri	-	x	x	-	x	-	-	x			
Eoannularia sp.	-	x									
Epistomina eocenica	-	x	-	-	x						
Eponides repandus var.	-	x									
Eponides scabriculus	-	x	x	-	-	x					
Eponides sp. nov.	-	x	-	-	x						
Frondicularia victoriae	-	x									
Gaudryina (Siphogenerina) victoriana	-	x									
Glabratella crassa	-	x									
Glabratella sp. nov.	-	x									
Globigerina pseudobulloides	-	x									
Globigerina triloculàris	-	x									
Globigerina triloculinoides	-	x	-	-	-	-	x	x			
Globulina gibba	-	x									
Globulina sp. nov.	-	x									
Guttulina clifdenensis	-	x									
Guttulina hantkeni	-	x									
Guttulina (Sigmoidina) silvestrii	-	x									
Gypsina globulus	-	x									
Gyroidina scrobriculata	-	x									
Heronallenia pusilla	-	x									
Karreriella siphonella	-	x	x	x							
Lagena favosopunctata	-	x	-	-	-	x					
Lagena striata	-	x	x								
Lagena sp. 1	-	x	x								
Lamarckina glencoensis	-	x									
Liebusella antipodum	-	x	x	-	-	-	-	x			
Pseudoglandulina clarkei	-	x									
Pseudopolymorphina rutila var. parri	-	x									
Pyrgo depressa	-	x									
Quinqueloculina singletoni	-	x	x	x							
Reussella pulchra	-	x									
Robulus alabamensus	-	x									
Sigmomorphina haeuslerii	-	x									
Sigmomorphina plummerae	-	x									
Sigmomorphina cf. trinitatensis	-	x									
Sigmomorphina williamsoni	-	x									
Sigmomorphina sp. nov.	-	x									
Sigmoilina chapmani	-	x	x								
Siphonina australis	-	x	x	-	-	x	x				
Sphaeroidina bulloides	-	x	-	-	-	-	x				
Triloculina tricarinata	-	x	-	-	x	x					
Triloculina trigonula	-	x	-	-	x						
Vaginulina legumen	-	x									
Vaginulina sp. nov.	-	x									
Discorbis bertheloti var.	-	-	x	x	x	-	x				
Dorothia subglabra	-	-	x	x							
Lenticulina crepidula	-	-	x								
Massilina torquayensis	-	-	x								
Patellina cf. corrugata	-	-	x								
Pseudoclavulina sp.	-	-	x								
Pullenia quinqueloba	-	-	x	-	-	x					
Textularia sp. nov.	-	-	x								
Globigerina cf. ouachitaensis	-	-	-	x	-	-	-	-	x		
Guttulina caudata	-	-	-	x							
Nonionella hantkeni	-	-	-	x							
Pyrulina fusiformis	-	-	-	x							
Sigmomorphina vaughani	-	-	-	x	-	x					
Ammodiscus cf. parri	-	-	-		x						
Cornuspira crassisepta	-	-	-		x	-	-	-	-	x	x
Cyclammina incisa	-	-	-		x						
Ellipsonodosaria cf. cocoaensis	-	-	-	-	x						
Pyrgo bulloides	-	-	-	-	x	x					
Quinqueloculina lamarckiana	-	-	-	-	x						
Quinqueloculina seminulum	-	-	-	-	x						
Quinqueloculina cf. vulgaris	-	-	-	-	x						
Spiroloculina canaliculata	-	-	-	-	x	x					
Robulus pseudocultrata	-	-	-	-	-	x					
Lagena scaraenensis var.	-	-	-	-	-	-	-	x			
Nodosaria raphanus	-	-	-	-	-	-	-	x			
Cibicides sp. 2	-	-	-	-	-	-	-	-	x		
Robulus inornata	-	-	-	-	-	-	-	-	x		

Table XI

Foraminifera	FD. 1,9, 10, 8.	FD. 11	FD. 12	FD. 13	FD. 2	FD. 3, 14	FD. 4	FD. 15	FD. 5, 6	FD. 16
Alabamina tuberculata var. australiensis	x	-	-	-	-	x				
Ammobaculites reophaciformis	x	-	-	-	x					
Angulogerina sp. 2	x									
Angulogerina sp. 9	x									
Anomalina ammonoides var. acuta	x	-	x	x	x					
Anomalina perthensis	x	-	-	-	x	x				
Anomalina subnonionoides	x	-	x	-	-	x				
Astrononion australe	x	-	-	-	x	x				
Bolivina cf. fastigia	x	-	-	-	-	x				
Bolivina hebes var. victoriensis	x									
Bolivina cf. nobilis	x									
Bolivina victoriana	x	-	-	-	x	x				
Bolivina sp. 2	x	-	-	-	x					
Cancris cf. intermedius	x									
Cassidulina inconspicua	x	-	-	-	x	x				
Cassidulina cf. inflata	x									
Cassidulina oblonga	x									
Cassidulina aff. pacifica	x									
Cassidulina subglobosa var. horizontalis	x									
Cibicides umbonifer	x	-	-	-	x	x				
Cibicides sp. 1	x	-	-	-	x	x				
Clavulinoides szaboi var. victoriensis	x	x	-	x	x	x	-	x	-	x
Cornuspira crassisepta	x	-	-	-	x					
Cyclammina incisa	x	-	-	-	-	-	x			
Dentalina fissicostata	x									
Dentalina cf. obliqua	x	-	-	-	-	x				
Dentalina soluta	x		-	-	x	x				
Dentalina subcostata	x	x								
Dorothia parri	x	x	-	x	x	-	-	-	-	x
Dorothia subglabra	x	-	-	-	x					
Epistomina eocenica	x	-								
Eponides scabriculus	x	-	x	-	x	x				
Globigerina cf. eocaenica	x	-	-	-	-	x				
Globigerina cf. dissimilis	x									
Globigerina mexicana	x	-	-	-	-	x				
Globigerina pseudobulloides	x	-	-	-	x	x				
Globigerina triloculinoides	x	-	-	-	x	x				
Globorotalia chapmani	x	-	-	-	x					
Globulina gibba	x									
Guttulina hantkeni	x									
Guttulina irregularis	x									
Guttulina (Sigmoidina) silvestrii	x									
Lagena apiculata	x									
Lagena favosopunctata	x									
Lagena cf. lagenoides	x									
Lagena scarenensis var. glabrata	x	x	x	-	x					
Lagena semistriata	x									
Lagena sp. 1	x									
Lenticulina gibba	x									
Notorotalia sp. 1	x	-	-	-	x					
Pseudopolymorphina clarkei	x	-	-	-	x					
Pullenia quinqueloba	x	-	-	-	-	x				
Quinqueloculina lamarckiana	x	-	-	-	x					
Quinqueloculina schrieberiana	x									
Reussella ensiformis	x									
Robulus alabamensis	x	x	-	-	x					
Robulus cf. knighti	x									
Robulus pseudocultrata	x									
Sigmoidella bortonica	x	-								
Siphonina australis	x	-	x							
Sphaeroidina bulloides	x	-	x	-	x					
Spiroloculina canaliculata	x									
Spirillina decorata	x	x								
Triloculina tricarinata	x									
Bolivina scalprata var. retiformis	-	x	x							
Cyclammina rotundata	-	x	-	-	-	-	-	x	x	x
Discorbis bertheloti var. nov.	-	-	x	-	x					
Lagena marginata	-	-	-	x	x					
Liebusella antipodum	-	-	-	x	-					
Sphaeroidina variabilis	-	-	-	x						
Anomalina westraliensis	-	-	-	-	x					
Bolivina cf. jacksonensis var. striatella	-	-	-	-	x	x				
Dentalina cf. semistriata	-	-	-	-	x					
Eponides repandus var.	-	-	-	-	x	x				
Gaudryina collinsi	-	-	-	-	x	x				
Globigerina ouachitaensis	-	-	-	-	x	x				
Lagena laevis	-	-	-	-	x					
Nodosaria pyrulata	-	-	-	-	x					
Quinqueloculina cf. agglutinans	-	-	-	-	x					
Sigmoilina chapmani	-	-	-	-	x					
Textularia fistulosa	-	-	-	-	x					
Angulogerina sp. nov.	-	-	-	-	x					
Bolivina sublobata	-	-	-	-	-	x				
Cassidulina armosa	-	-	-	-	-	x				
Cassidulinoides chapmani	-	-	-	-	-	x				
Dentalina cf. insulsa	-	-	-	-	-	x				
Nodosaria latejugata	-	-	-	-	-	x				
Robulus alato-limbosus	-	-	-	-	-	x				
Uvigerina cf. pigmea	-	-	-	-	-	x				
Vaginulinopsis gippslandicus	-	-	-	-	-	x				
Bathysiphon angleseaensis	-	-	-	-	-	-	x	x	-	x

TABLE XII

FORAMINIFERA	DM. 3	DM. 2	DM. 1	DM. 5	DM. 4
Amphistegina sp.	x	x			(
Anomalina subnonionoides	x	x	x		x
Calcarina sp.nov. (aff. mackayi).	x	x			
Cibicides perforatus var. notocenicus.	x				
Cibicides sp. 1	x	x	x	x	x
Dentalina fissicostata	x				
Dentalina subcostata	x	x			
Discorbis bertheloti var. nov.	x	x	-	-	x
Dorothia parri,	x	x	x	-	x
Globulina gibba.	x	x			
Guttulina hantkeni	x	x			
Guttulina (Sigmoidina) silvestrii.	x	x			
Notorotalia sp. 1	x	x	-	-	x
Pullenia quinqueloba	x	-	-	-	x
Sherbornina atkinsoni.	x				
Sigmoidella bortonica.	x	x			
Sigmoidella plummeriae	x				
Stomatorbina torrei,	x	x	-	-	x
Textularia abbreviata,	x				
Angulogerina subangularis.	-	x			
Angulogerina sp. 2	-	x	-	x	x
Anomalina ammonoides var. acuta.	-	x	x	-	x
Anomalina perthensis	-	x	-	x	x
Bolivina victoriana	-	x			
Buliminella madagascarensis var. spicata	-	x			
Buliminella pupa	-	x			
Buliminella westraliensis	-	x			
Cassidulina subglobosa var. horizontalis	-	x	-	-	x
Cibicides lobatulus.	-	x	x		
Cibicides perlucida.	-	x			
Cibicides umbonifer	-	x			
Cibicides vortex	-	x			
Clavulinoides szaboi var. victoriensis	-	x	x	x	x
Cornuspira byramensis	-	x	x	x	
Cornuspira striolata	-	x			
Dentalina soluta	-	x			
Dimorphina janjukensis	-	x			
Discorbis assulatus	-	x			
Discorbis margaritiferus	-	x	x		
Discorbinella sp. 1	-	x	x		
Discorbinella sp	-	x			
Eponides repandus var.	-	x	-	-	x
Frondicularia sp.	-	x			
Gaudryina collinsi	-	x			
Gaudryina (Pseudogaudryina) crespinae	-	x			
Globigerina triloculinoides	-	x	-	x	x
Karreriella siphonella	-	x			
Lagena apiculata	-	x	-	-	x
Lagena globosa	-	x			
Lagena hexagona	-	x			
Lagena laevis	-	x	-	x	x
Lagena orbignyana	-	x			
Lagena sp. 1	-	x			
Lamarckina glencoensis	-	x			
Nonionella hantkeni	-	x			
Pyrgo ringens	-	x			
Quinqueloculina cf. ammophila	-	x			
Quinqueloculina lamarckiana	-	x	x		
Quinqueloculina ornithopetra	-	x			
Quinqueloculina schreiberiana	-	x	x		
Quinqueloculina singletoni	-	x			
Quinqueloculina cf. vulgaris	-	x			
Quinqueloculina cf. whitei	-	x			
Reussella pulchra	-	x			
Rotorbinella finlayi	-	x			
Sigmoilina chapmani	-	x			
Sigmoilina victoriensis	-	x			
Siphonina australis	-	x	x		
Sphaeroidina bulloides	-	x	x		
Sphaeroidina variabilis	-	x			
Spirillina tuberculata	-	x			
Spirillina sp. nov.	-	x			
Textularia fistulosa	-	x			
Triloculina tricarinata	-	x	x		
Triloculina trigonula.	-	x	-	x	
Triloculinella oblonga	-	x			
Vaginulina cf. legumen	-	x			
Vaginulina cf. loeblichi	-	x			
Ammobaculites reophaciformis	-	-	x		
Bolivina cf. nobilis	-	-	x		
Cornuspira crassisepta	-	-	x	x	
Dentalina cf. obliqua	-	-	x	x	x
Dentalina soluta	-	-	x	x	
Epistomina eocenica	-	-	x	x	
Eponides scabriculus	-	-	x	x	
Nodosaria arundinea	-	-	x	-	x
Pseudoglandulina clarkei	-	-	x	x	x
Robulus alabamensis	-	-	x		
Spirillina decorata	-	-	x		
Spiroloculina canaliculata	-	-	x		
Astrononion cf. australe	-	-	-	x	
Bolivina sp. 2	-	-	-	x	
Dentalina filiformis	-	-	-	x	
Dentalina simplex	-	-	-	x	
Globorotalia chapmani	-	-	-	x	
Guttulina caudata	-	-	-	x	x
Heronallenia sp. nov. (aff. lingulata)	-	-	-	x	
Heronallenia vicksburgensis	-	-	-	x	
Lagena favosopunctata	-	-	-	x	x
Lagena marginata	-	-	-	x	
Lagena sulcata	-	-	-	x	
Sigmomorphina regularis	-	-	-	x	
Anomalina westraliensis	-	-	-	-	x
Bolivina crespinae	-	-	-	-	x
Bolivina cf. fastigia	-	-	-	-	x
Bolivina scalprate var. retiformis	-	-	-	-	x
Globigerina cf. angipora	-	-	-	-	x
Goesella rotundata	-	-	-	-	x
Lagena distoma	-	-	-	-	x
Lagena inflexa	-	-	-	-	x
Sigmoilina tenuis	-	-	-	-	x

TABLE XIII

FORAMINIFERA	BJ 8	BJ 7	BJ 6	BJ 1	BJ 2	BJ 3	BJ 4	BJ 5
Angulogerina australe	x	–	–	x	–	x		
Anomalina glabrata	x	x	x	x	x	–	x	
Anomalina subnonionoides	x	x	–	x	x	x	x	
Bdelloidina aggregata	x							
Bolivina arta	x	–	–	x	–	x		
Calcarina verriculata	x	–	–	x	–	x	x	x
Carpenteria rotaliformis	x							
Clavulinoides szaboi var. victoriensis	x	–	x	x	x	x		
Dentalina obliqua	x							
Dentalina semistriata	x							
Dentalina soluta	x	x	–	–	x			
Dentalina subcostata	x							
Dorothia parri	x	–	x	x	x	x		
Eponides repandus var.	x							
Gaudryina rugosa	x	–	x					
Glandulina laevigata	x							
Globigerina cf. bulloides	x	x	–	x	–	x	–	x
Globigerina cf. triloculinoides	x							
Globigerina cf. trilocularis	x	x	x	x	x			
Lagena sulcata	x							
Liebusella rudis	x							
Notorotalia howchini	x							
Quinqueloculina agglutinans	x							
Robulus articulatus	x							
Robulus sp.	x							
Sigmoidella cf. kagaensis	x	–	–	–	–	–	x	
Siphonina australis	x	x	x	x	–	x		
Triloculina tricarinata	x							
Cancris intermedius	–	x						
Cassidulina subglobosa	–	x	–	x	–	–	–	x
Nodosaria raphanus	–	x	–	x				
Bolivina cf. victoriana	–	–	x	–	x	x		
Cibicides sp. 1	–	–	x	x	–	x	x	
Guttulina problema	–	–	x	–	x			
Pyrgo bulloides	–	–	x					
Sphaeroidina bulloides	–	–	x	x	x			
Uvigerina hispida	–	–	x	x				
Anomalina glabrata	–	–	–	x				
Bolivina cf. antiqua	–	–	–	x				
Bolivina cf. plicatella	–	–	–	x				
Bolivina scalprata var. retiformis	–	–	–	x	–	x		
Calcarina aff. mackayi	–	–	–					
Cassidulina margaritea	–	–	–	x				
Cassidulinoides chapmani	–	–	–	x	–	x		
Cibicides sorrentae	–	–	–	x	x			
Cibicides sp. 3	–	–	–	x				
Discorbis margaritiferus	–	–	–	x				
Dyocibicides biserialis	–	–	–	x				
Lagena costata	–	–	–	x				
Lagena striata	–	–	–	x				
Nodosaria ovicula	–	–	–	x				
Patellina corrugata	–	–	–	x	–	x		
Planularia wuellerstorfi	–	–	–	x				
Pullenia bulloides	–	–	–	x				
Textularia cf. excavata	–	–	–	x				
Textularia sagittula	–	–	–	x				
Uvigerina multicostata	–	–	–	x				
Uvigerina pigmea var. asperula	–	–	–	x				
Angulogerina sp. 2	–	–	–	–	–	x		
Bolivina dilatata	–	–	–	–	–	x		
Bolivina sublobata	–	–	–	–	–	x		
Cibicides lobatulus	–	–	–	–	–	x	x	
Cibicides cf. vortex	–	–	–	–	–	x		
Cibicides sp. 2	–	–	–	–	–	x		
Heronallenia lingulata	–	–	–	–	–	x		
Lagena sp. 1	–	–	–	–	–	x		
Operculina victoriensis	–	–	–	–	–	x	x	
Pyrulina fusiformis	–	–	–	–	–	x		
Sherbornina atkinsoni	–	–	–	–	–	x		
Stomatorbina sp.	–	–	–	–	–	x		
Textularia abbreviata	–	–	–	–	–	x	–	
Uvigerina canariensis	–	–	–	–	–	x		
Crespinella umbonifera	–	–	–	–	–	–	x	
Elphidium pseudoinflatum	–	–	–	–	–	–	x	
Miniacum minutum	–	–	–	–	–	–	x	
Planorbulinella inaequilateralis	–	–	–	–	–	–	x	x
Planorbulinella plana	–	–	–	–	–	–	x	
Sherbornina sp. nov.	–	–	–	–	–	–	x	x
Amphistegina sp.	–	–	–	–	–	–	–	x
Elphidium parri	–	–	–	–	–	–	–	x

TABLE XIV

Foraminifera	T.8	T.1	T.2	T.3	T.4	T.5
Calcarina verriculata	×	×	×	×	×	×
Crespinella umbonifera	×	×	×	×	×	×
Operculina victoriensis	×	×	×	×	×	×
Planorbulinella plana	×	×	×	×	×	×
Sherbornina sp. nov.	×	×	×	×	×	×
Acervulina inhærens	—	×	×	×		
Anomalina subnonionoides	—	×				
Cassidulina subglobosa	—	×				
Elphidium parri	—	×	—	×	×	
Eponides repandus var.	—	×	—	×		
Gypsina globulus	—	×	×	×	×	×
Miniacina minutum	—	×	×	×	×	×
Planorbulinella inæquilateralis	—	×	×	×	×	×
Astrononion australe	—	—	×	×	×	×
Elphidium howchini	—	—	×	×	×	×
Globigerinoides trilobus	—	—	×	×		
Sigmoidella elegantissima	—	—	×	×		
Pseudopolymorphina rutila var. *parri*	—	—	—	—	×	

TABLE XV

Foraminifera	A.2	A.3	A.4	A.5	A.6	A.7	A.8	A.9	A.10	A.11
Calcarina sp. aff. *mackayi*	×	×	×	×	×	×	×	—	×	×
Calcarina verriculata	×	—	×							
Cibicides vortex	×	—	—	—	—	×				
Anomalina subnonionoides	—	—	×							
Crespinina kingscotensis	—	—	×	×	—	—	—	×		
Gaudryina (Siphogaudryina) victoriana	—	—	×							
Victoriella plecte	—	—	×	—	—	—	—	×		
Amphistegina sp.	—	—	—	—	—	×	×	×		
Crespinella sp.	—	—	—	—	—	—	—	×		
Planorbulina macphersoni	—	—	—	—	—	—	—	×	—	×
Elphidium howchini	—	—	—	—	—	—	—	—	—	×
Elphidium pseudoinflatum	—	—	—	—	—	—	—	—	—	×

Table XVI

DISTRIBUTION OF SPECIES IN STRATIGRAPHIC SEQUENCE THROUGH TORQUAY BORE (CHAPMAN, 1921), FB.SECTION (BETWEEN FISHERMAN'S STEPS AND BIRD ROCK, BR.SECTION (BIRD ROCK) TO T.SECTION (HEADLANDS SOUTH OF MOUTH OF SPRING CREEK).

x Described from Eocene in Australia and new species.
ø Described from Eocene elsewhere
+ Described from Palaeocene
/ Described from Lower Oligocene
♝ Described from Upper Oligocene
ж Described from type locality, Janjukian Stage, at Bird Rock
o Described from Lepidocyclina beds and equivalents (lr.Miocene), Australia.
(Described from Balcombian Stage (?lr.Miocene) of Hall and Pritchard and of Singleton
⌿ Described from Miocene elsewhere

Column groups: UPPER EOCENE — Torquay Bore (Chapman, 1921): 69–70, 64–65, 58–59, 53–54, 49–50, 42–43, 37–38, 34–35, 27–28, 24–25, 13–14, 5'9"–6'6"; Between Fisherman Steps and Bird Rock: FB.1&A, FB.2, FB.3, FB.4, FB.5; Bird Rock Section: BR.18, BR.17, BR.14, BR.5, BR.4, BR.3, BR.2, BR.1, BR.6, BR.7, BR.8, BR.9, BR.10, BR.11, BR.12, BR.13. MIOCENE — Headland S. of mouth of Spring Ck.: T.8, T.1, T.2, T.3, T.4, T.5.

FORAMINIFERA
Calcarina sp.nov. aff. C.mackayi Karrer
Clavulinoides szaboi (Hantk.) var. victoriensis Cush
Stomatorbina torrei Cushman & Bermudez
Liebusella antipodum (Stache)
Quinqueloculina ornithopetra Crespin
Quinqueloculina singeltoni Crespin
Dorothia parri Cushman
Sigmoilina victoriensis Cushman
Dimorphina janjukensis Crespin
Cassidulina oblonga Reuss
Victoriella plecte Chapman
Massilina torquayensis (Chapman)
Siphonina australis Cushman
Alabamina sp.nov.
Angulogerina australe (Heron-Allen & Earland)
Angulogerina sp.nov.
Anomalina subnonionoides Finlay
Anomalina perthensis Parr
Astrononion cf. australe Cushman
Bolivina fastigia Cushman
Bolivina victoriana Cushman
Bolivina sp. 1 aff. B.spiralis Cushman
Bolivina sp. 2.
Bolivinella subpectinata Cushman var.nov.
Bolivinopsis crespinae Parr
Bulimina pupula Stache
Buliminella pupa (Terquem)
Buliminella westraliensis Parr
Cassidulina armosa Bandy
Cassidulina subglobosa d'Orb var. horizontalis Cush.
Cassidulinoides chapmani Parr
Ceratobulimina westraliensis Parr
Cibicides pseudoconvexus Parr
Cibicides umbonifer Parr
Cibicides vortex Dorreen
Cibicides sp. 1
Cornuspira byramensis Cushman
Cyclammina rotundata Chapman & Crespin
Dentalina fissicostata Gumbel
Dentalina subcostata Chapman
Discorbis assulatus Cushman
Discorbinella sp.nov. aff. D.concava (P.&J.)
Discorbis margaritiferus (H-A.& E.)
Dorothia subglabra (Gumbel)
Eponides repandus (F.& M.) var.nov.
Frondicularia victoriae Crespin
Gaudryina collinsi Cushman
Gaudryina (Pseudogaudryina) crespinae Cushman
Glabratella crassa Dorreen
Glabratella petalifera (Howe)
Glabratella sp. 1
Globigerina pseudobulloides Plummer
Globigerina triloculinoides Plummer
Globorotalia chapmani Parr
Guttulina hantkeni Cushman & Ozawa
Guttulina (Sigmoidina) silvestrii Cushman & Ozawa
Gyroidina scrobiculata Finlay
Karreviella siphonella (Reuss).
Lagena scarenensis Hantken var. glabrata Selli
Lagena selseyensis Heron-Allen & Earland.
Lamarckina glencoensis Chapman & Crespin.
Planorbulina macphersoni Finlay
Pseudoglandulina clarkei Parr
Pyrulina sp.nov.
Quinqueloculina cf. mauricensis Howe
Quinqueloculina venusta Karrer
Quinqueloculina cf. whitei Beck
Reussella cf. decorata (Heron-Allen & Earland)
Rotorbinella finlayi Dorreen
Sherbornina atkinsoni Chapman
Sigmoilina chapmani Cushman
Sigmomorphina vaughani Cushman & Ozawa
Vaginulina cf. loeblichi McLean
Angulogerina sp. 3
Bolivina jacksonensis Cushman & Applin.
Bolivina cf. sublobata Cushman
Bolivina sp.nov. aff. B.crenulata Cushman
Eponides sp.nov.
Gutulina spicaeformis (Roemer).
Lagena sp.2
Sigmoidella bortonica Finlay
Sigmomorphina schencki Cushman & Ozawa
Alabamina tuberculata (B.& V.) var. australiensis C.P.& C.
Angulogerina sp. 2
Annulopattelina sp.nov.
Anomalina grosserugosa Gumbel
Baggatella sp.
Bolivina crespinae Cushman
Cassidulina cf. inconspicua Hussey
Ceratobulimina dehiscens (Chapman, Parr & Collins)
Ceratobulimina sp.nov.
Cassidulinoides cf. howei Cushman
Cibicides perforatus (Karr.) var. notocenicus Dorreen
Cibicides sp.2
Eponides scabriculus (Chapman)
Globigerina cf. dissimilis Cush.& Bermudez
Globigerina mexicana Cushman
Globigerina ouachitensis Howe
Heronallenia pusilla Parr
Lagena gracilicostata Reuss
Lagena grinzingensis Karrer
Lagena pulcherrima Cushman & Jarvis
Lagena spiralis Br. var. cubensis Palm. & Berm.
Lagena cf. watsonae Martin
Lamarckina cf. haliotis Heron-Allen & Earland
Nonionella hantkeni (Cushman & Applin).
Pseudopolymorphina subnodosa (Reuss).
Reussella pulchra Cushman
Robulus alabamensis Cushman
Elphidium pseudoinflatum Cushman
Guttulina caudata d'Orb.
Notorotalia sp.nov. aff. N.tainuia Finlay.
Quinqueloculina sp.nov.
Sigmoidella plummerae Cushman & Ozawa
Sigmomorphina haeusleri Parr & Collins
Sigmomorphina jacksonensis Cushman
Alabamina tenuimarginata (Chapman, Parr & Collins)
Angulogerina subangularis Parr
Anomalina ammonoides (Reuss) var. acuta Plummer
Bolivina scalprata Schw. var. retiformis Cush.
Buliminella madagascarensis (d'Orb.) var. spicata C.& P.
Carpenteria rotaliformis Chapman & Crespin
Epistomina eocenica Cushman
Guttulina jarvisi Cushman & Ozawa
Heronallenia vicksburgensis Cushman
Hopkinsina bortotara Finlay
Lagena cf. lunata Matthes
Lagena sp. 1
Lagena sp. 3
Lagena sp. 4
Pseudopolymorphina cf. decora (Reuss)
Spirillina sp.nov.
Bolivina cf. nobilis Hantken
Bolivina cf. plicatella Cushman
Bulimina tarda Parker & Bermudez
Buliminella obtusata Cushman
Cibicides perlucida Nuttall
Dentalina sp.nov.
Gaudryina (Pseudogaudryina) sp.nov.
Globigerina eocaena Gumbel
Guembelina cf. goodwini Cushman & Jarvis
Hauerina tateana (Howchin)
Heronallenia sp.nov.
Lagena perthensis Parr
Lagena sp. 5.
Nodosaria longiscata d'Orb.
Plectofrondicularia sp. nov.
cf. Pseudobulimina glaessneri Howe
Rotalia sp. nov.
Spiroplectammina cf. wilcoxensis Cushman
Textularia aff. lalickeri Cushman & Renz
Textularia cf. pectinata Reuss
Vaginulina sp. 1
Virgulina schreibersiana Cz.
Dentalina jacksonensis Cushman
Dentalina sp. 1
Pseudopolymorphina sp.nov.
Sigmomorphina cf. trinitatensis Cushman & Ozawa
Alabamina obtusa (B.& H.) var. westraliensis Parr
Allomorphina cf. trigona Reuss var. obtusa Andreae
Angulogerina cf. rugoplicata Cushman
Angulogerina sp.nov.
Articulina cf. advena (Cushman)
Articulina cf. victoriana Cushman
Bolivina cf. byramensis Cushman
Bolivina cf. gardnerae Cushman
Bolivina cf. mississippiensis Cush. var. costifera Cush.
Bolivina cf. peruviana Cushman & Stone
Bolivinella compressa Howe
Cassidulina globosa Hantken
Ceratobulimina cf. lornensis Finlay
Crespinella sp.nov.
Cycloloculina sp.nov.
Dentalina cooperensis Cush. var. gracilescata Cush.
Discorbis cf. bulla Cushman
Discorbis cf. huneri Howe
Ellipsonodosaria cocoaensis Cushman
Globigerinoides index Finlay
Globorotalia sp.nov.
Gyroidina soldanii (d'Orb.) var. octocamerata C.& H.
Guembelina venezuelana Nuttall var. rugosa Parr
Hantkenina alabamensis Cush. subsp. compressa Parr
Hauerina sp.nov.
Lagena curvi-costata Heron-Allen & Earland
Lagena orbignyana (Seg.) cf. var. crenulata Cushman
Lagena orbignyana (Seg.) cf. var. trinitatensis Nuttall
Lagena tenuis (Born.) var.
Lenticulina convergens (Born.)
Loxostomum wilcoxensis Cushman & Ponton
Nonionella cf. zenitans Finlay
Reussella cf. oberburgensis (Freyer)
Robertina ovigera Terquem
Robertina wilcoxensis Cushman & Ponton
Robulus arcuato-striatus (Hantken)
Robulus limbosus (Reuss)
Spiroplectammina mississippiensis Cushman
Tutulogenerina vicksburgensis Howe
Vaginulina schwageri Hantken
Vaginulinopsis gippslandicus (Chapman & Crespin)
Virgulina dibollensis Cushman & Applin
Cyclammina incisa Stache
Anomalina cf. macroglabra Finlay
Anomalina cf. pinguiglabra Finlay
Lagena mississippiensis Cushman & Todd
Lagena orbignyana (Seg.) var. pileata Matthes
Lagena wallacei Bandy
Reussella spinulosa (Reuss)
Calcarina cf. verriculata (Howchin & Parr)
Cibicides victoriensis Chapman, Parr & Collins
Globigerinoides trilobus (d'Orb.)
Globulina inaequalis Reuss
Planulina cf. mexicana Cushman
Pyrulina thouini (d'Orb.)
Robulus cf. inornatus (d'Orb.)
Glandulina laevigata Reuss
Robulus articulatus (Reuss).
Operculina victoriensis Chapman & Parr
Robulus cf. cultratus (Montf.) var. antipodum Stache
Robulus nigriseptus Koch
Calcarina verriculata (Howchin & Parr)
Crespinella umbonifera (Howchin & Parr).
Planorbulinella plana (Heron-Allen & Earland)
Sherbornina sp.nov.
Elphidium howchini Cushman
Miniacina minuta (Chapman)
Planorbulinella inaequilateralis (Heron-Allen & Earland)
Gypsina howchini Chapman
Pseudopolymorphina rutila Cush. var. parri Cush. & Ozawa

PETROGRAPHY OF SEDIMENTARY ROCKS FROM THE TORQUAY-EASTERN VIEW AREA, VICTORIA

By W. B. Dallwitz, B.A., M.Sc.

[Read 8 July 1954]

In the course of the detailed investigation of measured sections in the Torquay-Eastern View area by Dr. Raggatt and Miss Crespin (1954), rock specimens were submitted for petrographical determination. This short paper gives the result of this examination. The numbers of samples, such as BR.5 and EV.3, refer to those given by Raggatt and Crespin in their Sections 7 and 23.

White Rock from near top of Addiscot Member, collected from western end of Demon's Bluff cliffs, east side of Anglesea River

Most of this specimen is very fine-grained — average grain size 0·005 to 0·0025 mm. It contains a few quartz grains of average diameter 0·1 mm., and also a little clay. Its specific gravity is 2·58. Excepting the clay and quartz, the rock is soluble in hot sulphuric acid; from the solution aluminium hydroxide was precipitated by adding ammonium hydroxide. The greater part of the rock is soluble in caustic soda solution also. Water is given off on heating in the closed tube. The refractive index of the soluble material is about 1·557.

These tests indicate that the soluble mineral is gibbsite. The low double refraction (too low for gibbsite), as observed in thin section, is due to the extremely fine grain-size of the mineral. Gibbsite has a specific gravity of 2·35±; the figure 2·58 is high, but would probably be accounted for by the impurities mentioned, and by any boehmite (S.G. 3·01 - 3·11) which may be present in a rock of this kind, but was not actually determined.

A mottled yellowish grey (5Y7/2)* and dark grey (N3) substance, which borders and marginally penetrates the gibbsite as veinlets, was also examined, and was found to consist essentially of montmorillonite containing irregularly distributed angular grains of quartz (average grain-size 0·1 mm.), which may occupy up to 35 per cent by volume of this part of the rock. Minor constituents are fragments of felsite or chert, black iron-ore, leucoxene, zircon, and rutile. The montmorillonite is patchily and lightly stained by limonite, and generally has aggregate polarization.

Refractive index measurements, which formed the basis of the determination of the montmorillonite, yielded the following results:

(i) Yellowish grey material .. .. .. 1·515±
(ii) Dark grey material .. .. 1·500±

These figures lie within the ranges recorded for different types of montmorillonite.

Bright green material (glauconite (?)) from the top of the Jan Juc Formation (B R.5), Bird Rock Point

In the hand specimen, this material is coloured dusky green (5G3/2), and has a somewhat velvety appearance. Nests of minute octahedra of pyrite are present in small hollows and open cracks and, to a lesser extent, in the body of the rock.

* Colours recorded are as defined in the "Rock-Color Chart" of the National Research Council, Washington, D.C.

K

Measurements with immersion media showed that the mean refractive index of the green mineral is approximately 1·560; this figure is very much below the lower limit of the range usually stated for the mean index of glauconite, viz. 1·609 to 1·643, and is close to those recorded by Dallwitz (1952, p. 55) for glauconite from Maslin Bay, South Australia; it is also lower than the actual limits (1·575 to 1·602) found by Glover (1954) in glauconite from rocks of the Torquay-Airey's Inlet area. These discrepancies suggest that chemical and optical work should be done to establish the full ranges of composition and optical properties of the group of minerals broadly classed as glauconite; such work may also throw light on the origin of different types of glauconite, and on the conditions of sedimentation and diagenesis which may be responsible for the differences.

In thin section the glauconite is coloured bright yellow green, and has embedded in it scattered quartz grains, shell fragments and foraminiferal tests, and rare pyrite, all of which make up not more than 5 per cent of the whole rock. The chambers of the foraminifera are filled with glauconite. Some of the glauconite is coarse-grained; one area which extinguishes as a unit measures 2·5 mm. x 2·5 mm.

Part of the specimen could not be successfully sectioned. On crushing, this was found to consist of quartz, shell fragments, glauconite, foraminiferal tests partly or wholly filled with glauconite, and claystone.

It is probable that the glauconite in this rock has been derived from clay. No clay remains in the sectioned part of the specimen, but some was observed in crushed material from another part of the rock. (See above.)

Concretions in top of Jan Juc Formation (B R.5) at Bird Rock Point

The sample is a friable, clastic rock, consisting of two distinct parts. One part, which may be considered as the matrix of the other, is coloured very light olive green (5Y7/1), and consists of shell fragments, shells, quartz grains, and glauconite. The other part (the "concretions") is composed of light olive grey (5Y6/1) claystone containing shell fragments, shells, and a high percentage of somewhat irregularly distributed glauconite; small scattered crystals and grains of pyrite can be identified with the aid of a lens. Where the claystone contains no glauconite, it has conspicuous shrinkage cracks. The glauconite ranges in colour from greyish-green (10GY5/2) to dusky yellow green (5GY5/2).

The mutual relationships of the two parts of the rock cannot be conclusively determined from the sample. However, it appears probable that the more argillaceous glauconite-rich masses have been laid down as infillings of the troughs of water-current ripple marks preserved in a less argillaceous rock. Certain environmental conditions implied by the presence of ripple marks are consistent with those under which some authors consider many glauconitic rocks to have been formed (Lochman, 1949, p. 56; Imlay, 1949, pp. 90-91).

The "matrix" is composed of shell fragments, clay which is mostly bonded by calcite, quartz grains, glauconite, and foraminiferal tests. Microscopically, it is impossible to estimate, even approximately, the ratio of carbonate to clay; however, it is clear that the percentage of clay is very much less than that of carbonate. The quartz grains are angular, and have an average size of 0·07 mm.; they make up 15 to 20 per cent of the rock. Glauconite is present to the extent of about 3 per cent. Most of it belongs to Glover's first class—that is, it is or was included in tests of organisms, particularly gastropods, foraminifera, and parts of echinoid plates. In some cases only the outer chambers of foraminifera contain glauconite, and, in fact, most of the foraminiferal tests are free from this mineral. Only a few of the broken echinoid plates contain glauconite, and mostly only a group of pores

in any one plate fragment is filled with glauconite. Some of the glauconite falls into Glover's second class; generally, this glauconite takes the form of oval to semi-oval and irregular masses with sharp boundaries, and appears not to have been enclosed within tests of organisms at any time. In addition, a few oval grains ((?) coprolitic mud) show only incipient glauconization, a stage in which a strong overall tinge of green has been imparted to the originally brown grain. Finally, a little of the glauconite has "indefinite boundaries" which appear to grade imperceptibly into the surrounding argillaceous and calcareous material (Glover, 1954, p. 154).

Accessory minerals—black iron-ore, pyrite and zircon—are very rare in this part of the rock.

The "matrix" is a clayey, sandy and shelly calcareous calcarenite, containing a small percentage of glauconite.

The glauconite-rich rock associated with that described above differs from it in the following ways:

(i) Quartz is less plentiful—it makes up 5 to 7 per cent of the rock, as compared with 15 to 20 per cent in the "matrix".
(ii) Clay is much more plentiful, and a high proportion of it is not bonded by calcite.
(iii) Glauconite is an important component. It is irregularly distributed, and makes up about 15 per cent of the rock.

Thus the major constituents of this part of the rock are calcite (as broken and unbroken shells), clay, glauconite and quartz, in order of decreasing abundance. Accessory minerals are quite rare, and consist of pyrite, black iron-ore, probable marcasite, and fine flakes of muscovite. The rock is a clayey, glauconitic, and silty calcareous calcarenite, containing numerous shells and shell fragments.

Recognizable shell fragments and complete skeletons comprise lamellibranchs, foraminifera, gastropods, echinoids (parts of plates and spines), and bryozoa. Perforated or ornamented spherules or cylinders of calcite, representing organisms or parts of organisms, are conspicuous in some places, but occupy probably less than 0·1 per cent by volume of the rock.

The pyrite, which occurs as irregular grains, cubes and octahedra, is generally enclosed in or closely associated with glauconite; it is commonly bordered by black iron-ore, separate grains of which are also scattered through the rock. The (?)marcasite is found as aggregates or strings of minute grains embedded in the clayey, calcareous cement. The black iron-ore which is associated with the (?)marcasite is more abundant in some parts of the rock than in others.

Glauconite occurs in all of the ways previously described for the "matrix", but dominantly as sharp-bordered oval and irregular grains, as distinct from infillings of shells. It appears to have been derived from clay or from coprolitic pellets, and its abundance is a reflection of the abundance of clay in this part of the rock, as compared with the "matrix". The predominance of this type of glauconite lends support to the idea that mud is commonly the progenitor of this material.

In some places bodies of glauconite simply grade outwards, by decrease of that mineral, into the surrounding clay; in other places clay is only lightly impregnated with glauconite. Both of these modes of occurrence are essentially the same, and they strongly suggest that the glauconite has been derived directly from clay.

Many of the probable coprolitic pellets that have been converted to glauconite contain minute grains of quartz (see Figs. 4, 5 and 7, Takahashi and Yagi, 1929, p. 845).

Some of the glauconite which occurs in the tests or organisms does not completely fill them, but appears to have shrunk away from the walls; this condition is particularly conspicuous where the mineral is contained in the openings of a bryozoal skeleton. In some places the tests are partially broken and/or dissolved, but the original shape of the enclosed glauconite masses is retained.

All the glauconite shows aggregate polarization. Its refractive indices are lower than those usually recorded, and differ from one mass to another. Most aggregates have a R.I. of about 1·565, but some fall below 1·560, and others range above 1·570. This apparent lack of constancy in composition would make definitive chemical and optical work on such a sample very difficult, but would still allow significant generalized data to be obtained.

Specimen from Great Ocean Road, ½ mile west of Painkalac Creek (Airey's River) Bridge—EV.3

This is a friable, mottled rock with the texture of a claystone; it is externally and internally traversed by a network of shrinkage cracks. The principal colours giving rise to the mottling are moderate red (5R4.5/4) and dark red (5R4/4). Another prominent colour is pale yellowish grey (5Y7.5/2), but this appears mainly in one band; scattered pale greyish yellow (5Y8.5/4) flecks are also present.

Microscopically, the rock is found to consist of a fine-grained, dark yellowish brown (10YR4.5/2) matrix in which are embedded very irregularly shaped fragments of devitrified glass and angular fragments of quartz.

The matrix is volcanic ash. It is invariably darker than average in a zone about 0·025 mm. wide round the borders of the glass fragments. Differences in concentration of clots and disseminated particles of haematite in the matrix impart the mottling to the hand specimen.

The outlines of the glass fragments are extremely ragged, as would be expected in a tuff. Their average size is about 0·3 mm., and the largest measures 1·25 mm. Quartz grains are included in some of the fragments.

In the slide examined the dimensions of the quartz grains range between 1·75 mm. and 0·01 mm., but most are about 0·3 mm. across. Shattering in a few grains confirms the suggested explosive volcanic origin of the rock. Felspar may have been present, but if so, it is now so much altered that it can no longer be distinguished.

Single grains each of zircon and tourmaline are the only accessories noted.

The estimated percentages of the major constituents are: haematite-stained ash 67, devitrified glass 19, and quartz 14.

The rock is an acid ashstone containing fragments of devitrified glass and of quartz.

Anglesea Member — Type locality

The specimen is a fine-grained, clastic, friable and coarsely mottled rock whose colouring ranges between dusky yellowish brown (10YR2/2) and light yellowish brown (10YR5/2). Bedding is not prominent; where visible it is in the form of discontinuous bands of different colour from 1 mm. to about 1 cm. thick, and showing evidence of current action. Only scattered flakes of muscovite can be conclusively identified with the aid of a lens.

On strong heating the rock is bleached and gives off an odour of burning coal.

For microscopic examination the darkest part of the rock was sectioned.

Quartz is the dominant mineral. Very few of the grains are rounded; most are angular, some are splintery, and a few subangular. Their grain-size is fairly uniform, and averages 0·05 mm.

The quartz grains are set in a matrix of carbonaceous clay. This matrix may occur interstitially between the quartz grains, or as irregular clots and bands containing a few grains of quartz, sericite, chlorite, marcasite, and felsitic igneous rock or chert; the size of these included grains ranges from 0·05 mm. down to 0·005 mm. or less. In colour the carbonaceous clay ranges between very dark orange brown (10YR3/6) and dusky orange brown (10YR2/6), according to the degree of concentration of carbonaceous matter. The clay has probably been derived from a vegetable slime. Small irregular bands and clots of brown coal represent strong concentrations of carbonaceous matter.

Unevenly distributed through the rock are fragments of a chloritic mineral, possibly altered and leached chamosite, occurring in grains of about the same size as those of quartz. This mineral is length slow and biaxial negative with low optic axial angle; it has micaceous cleavage and straight extinction, may be faintly pleochroic, and has a double refraction of approximately 0·005. In colour it ranges between pale greyish yellow (5Y8.5) and dusky yellow (5Y6/4); these differences may be partly due to staining by organic material. Some grains show aggregate polarizatin.

Minor constituents, approximately in order of decreasing abundance, are chert or fragments of felsite, marcasite, muscovite, leucoxene, felspar (acid plagioclase, orthoclase, and microline), brown and green tourmaline, zircon, very rare glauconite, ilmenite, monazite, and (?)cassiterite. The last three minerals were found in the residue obtained by panning.

The sectioned portion of the rock consists of an estimated 50 per cent quartz, 38 per cent clayey and carbonaceous cement, 5 per cent chlorite, 2 per cent (?)chert, and 5 per cent other constituents, and is a clayey, carbonaceous greywacke-siltstone.

(It is to be noted that, in describing the colour of the matrix of this rock, the colour names "very dark orange brown" and "dusky orange brown" are used. These colours do not appear on the colour chart, and so the above colours and their names were chosen more or less by guesswork. The colour name "pale greyish yellow" for the chloritic mineral was arrived at in a similar way.)

Addiscot Member — Demon's Bluff cliffs

The sample is a friable, non-bedded, medium-grained clastic rock, in which, in the hand specimen, only scattered flakes of muscovite can be identified. In one area small dark clots, apparently rich in carbonaceous material, are visible. The colour of the rock is very pale yellowish brown (10YR7/2).

Microscopically the rock is seen to consist essentially of even-grained quartz grains in a matrix of clay.

The quartz grains are angular to sub-angular, and a few are splintery. Their average grain-size is 0·07 mm.

The clay is unevenly distributed, and is irregularly, though lightly, stained by limonite.

Other constituents of the rock are rounded fragments of felsite or chert, leucoxene, ilmenite, brown and green tourmaline, chlorite, muscovite, felspar (acid plagioclase, orthoclase, and microline), zircon, rare granular limonite, and very rare epidote and probable glauconite. In a dish concentrate rutile and a little monazite were found in addition; this concentrate also revealed some perfect, water-

clear, doubly-terminated crystals of zircon, which may have formed during diagenesis. No carbonate was noted in the slide, but slight effervescence took place when the rock was attacked with cold dilute HCl, and further effervescence occurred in hot concentrated HCl.

The rock consists of about 55 per cent quartz, 38 per cent limonite-stained clay, and 7 per cent other minerals, and is a very fine quartz-clay greywacke.

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7

PETROGRAPHICAL STUDY OF ROCK SAMPLES FROM THE COASTAL SECTION BETWEEN TORQUAY AND AIREY'S INLET, VICTORIA

By J. E. Glover, B.Sc., Ph.D.

Petrographical descriptions are given here of twenty-five specimens of sedimentary rocks which H. G. Raggatt collected from different measured sections during the preparation of the paper with Miss Crespin on "Stratigraphy of Tertiary Rocks between Torquay and Eastern View, Victoria" (1954). The sections from which the specimens were collected are given below and their exact stratigraphical position in the section can be identified by reference to that paper. All sedimentary rocks from the area have been named according to the classification drawn up by M. A. Condon (1953). The results of a rough chemical analysis made in 1947 on a sample of supposed jarosite (W.12) are given and a note on the occurrence and possible origin of the glauconite found in many of the samples, is appended.

The rocks herein described are as follows:

Section 7—Bird Rock and adjacent Bluff

Hard Bed 7 in. thick in BR.12,
Bed "N" in BR.9
Bed "M" in BR.9,
Bed "L" at base of BR.9,
Bed "K" in BR.7,
Bed "J" in BR.7,
BR.7,
Bed "H" in BR.6,
Jarosite ?, Base of BR.4,
BR.4,
BR.5,
BR.14,
Hard Band in BR.14.

Section 9—Between Fisherman's Steps and Bird Rock

FB.4,
FB.3.

Section 12—Between Fisherman's Steps and Dead Man's Gully

Bed "K",
Bed "J",
Bed "H",
FD.7.

Section 6—Rocky Point

Bed "B" in RP.3,
Bed "A" in RP.1.

Section 3—Between Soapy Rocks and Point Roadknight

W.98,
W.12.

Section 19—Airey's Inlet

A.1 (2 specimens).

SECTION 7—BIRD ROCK AND ADJACENT BLUFF

Hard Bed 7 in. thick in BR.12

The rock is white, fairly compact, partly iron-stained and exhibits no bedding or lamination in the hand specimen. The only mineral which can be distinguished with the naked eye is mica which occurs sparingly as small flakes. The rock effervesces with cold N/10 HCl.

Under the microscope the rock is seen to consist of a finely granular mass of grey, somewhat turbid carbonate (average diameter of grains 0·01 mm.) together with foraminiferal tests, glauconite, pyrite and a little mica. The matrix may be a re-crystallized lime-mud.

Foraminiferal tests represent only 2 per cent of the rock and many of them are completely filled with glauconite. Other glauconite is not enclosed within tests, and occurs as small grains which are bounded by crystalline carbonate. The glauconite, whether free or enclosed, shows alteration to limonite.

Quartz, present as small angular grains with an average diameter of about 0·05 mm., makes up 5 per cent of the rock. Other minerals present are muscovite and biotite, as scattered small flakes, black iron ore as small grains, and limonite, mainly in form of red brown stains which impregnate the carbonate in places.

The rock is a silty calcilutite.

Bed "N" in BR.9

This rock is fine grained, grey-white but stained pale orange in patches, slightly friable and unlaminated. It effervesces only slightly with cold N/10 HCl.

In thin section, the rock is seen to consist of a finely granular mass of carbonate and angular quartz grains. The carbonate, which shows no sign of organic structure and occurs as grains with an average diameter of 0·05 mm., makes up about 90 per cent of the rock. Many of the grains are rhombs, and are probably dolomite. Quartz, angular and similar in grain size to the carbonate, makes up 5 per cent of the whole.

A few small, brownish-green, ovoid grains which appear to have aggregate polarization probably represent glauconite which has been partly converted to limonite. Other limonite stains and patches are scattered throughout the slide, and a few grains of black iron ore, a little green biotite and some colourless muscovite are also present.

This rock is a silty dolomitic limestone (calcilutite).

Bed "M" in BR.9

This rock is grey-white and fine grained with pale red-brown patches due to the oxidation of ferrous iron. It is slightly friable and contains white foraminiferal tests which are clearly visible to the naked eye. It effervesces with cold N/10 HCl.

Under the microscope, the rock is seen to be made up of a finely-divided, grey, somewhat turbid mass of carbonate, probably with a little argillaceous matter, containing quartz grains, a few shell fragments, patches of limonite and some clearly defined foraminiferal tests. Many of the red-brown limonite patches surround a darker core which resembles a foraminifer in shape. This, together with the fact that small portions of some patches have a yellow-green tint, suggests that at least some of the limonite is secondary after glauconite.

Quartz is very angular and is made up of grains having an average diameter of the order of 0·05 mm.; these grains, with a little chalcedony and felspar, com-

prise possibly 5 per cent of the rock. Also present are a few grains of black iron ore and flakes of muscovite.

This rock is a silty calcilutite.

Bed "L" at base BR.19

The rock is white, stained orange by iron oxide. It is fairly friable, fine-grained and contains a few shell fragments. It effervesces slightly with cold N/10 HCl.

Under the microscope, the rock consists of a grey, turbid mass of finely-divided carbonate, slightly iron stained in patches, containing angular quartz grains, foraminiferal tests and a few shell fragments. Organic remains form less than 3 per cent of the whole. The tests contain material, apparently mostly of clay with a little carbonate which has been stained brown—this stain commonly extends beyond the walls of the tests to form irregular patches in the surrounding rock. Other brownish patches, which in places have cores of green, chloritic or glauconitic material, are scattered throughout the rock; some of these appear not to have been enclosed in foraminifera.

Quartz grains, which are angular and have an average diameter of 0·05 mm., make up 20 per cent of the rock. A little muscovite and a few small grains of black iron ore are the only other minerals present.

This rock is a silty, calcareous claystone.

Bed "K" in BR.7

The rock is grey, with large red-brown patches due to iron staining, and is fairly friable, with no discernible bedding. It effervesces with cold N/10 HCl.

Microscopically, the rock consists mainly of granular carbonate having no obvious organic structure and an average grain diameter of 0·05 mm. Quartz, which is markedly angular, makes up only 1 per cent of the rock. Other minerals present in small quantity are black iron ore, pyrite, limonite, and little clay, and a few grains of a green mineral, probably glauconite.

The rock is calcilutite.

Bed "J" in BR.7

This rock is grey, somewhat friable and shows no lamination in hand specimen and contains white shell fragments. It effervesces with cold N/10 HCl.

Microscopically, the rock consists of carbonate (82 per cent), quartz grains (15 per cent), and pyrite (3 per cent). The carbonate is colourless, cloudy or brown—some of the brown material obviously has an immediate organic origin and is present in form of shell fragments and broken foraminiferal tests; but most of the carbonate is finely granular perhaps from re-crystallization of lime-mud. The quartz grains, which are angular, exhibit remarkable uniformity of size (average diameter 0·06 mm.). Pyrite is scattered throughout the carbonate as small irregular grains. Also present are a little green chloritic material, a few flakes of brown biotite and some angular grains of sodic plagioclase.

The rock is a silty calcilutite.

BR.7

This rock is grey and very friable, and shows no bedding or lamination in the hand specimen. Small shell fragments, tiny specks of mica and a little pyrite can be seen in the fine grey base which is apparently partly calcareous and partly argillaceous. The rock effervesces with cold N/10 HCl.

In thin section the rock is seen to be made up of a yellow-brown base, organic remains, quartz, pyrite and glauconite. Most organic remains consist of broken

foraminiferal tests—usually of colourless to somewhat turbid carbonate, and a few consist of elongate or irregularly shaped, brown, turbid fragments derived from larger organisms. The yellow-brown base is very fine and is difficult to resolve into its components under the microscope—it seems to be made up mainly of argillaceous material, fine quartz, black iron ore and pyrite, mica and possibly felspar. Some finely disseminated carbonate is probably present. Green glauconite, with aggregate polarization, is scattered rather sparingly throughout the slide in the form of ovoid pellets. Rare grains of glauconite which seem to grade into the yellow-brown material are also present—these are not well defined and appear in places as small greenish patches. Foraminifera are numerous, but none in this slide seems to contain glauconite.

Angular quartz is fairly abundant as grains with an average diameter of 0·08 mm. Mica consists mainly of muscovite, green biotite and a few flakes of brown biotite. A little chlorite may be present, but this is difficult to distinguish from the small green glauconite patches. The only other mineral noted consists of a rare grain of brown tourmaline.

The estimated composition of the rock is as follows:

Yellow-brown base	41%
Carbonate	33%
Quartz	22%
Pyrite	3%
Mica, glauconite	1%

This rock is a sandy foraminiferal marl.

Bed "H" in BR.6

This rock is grey, silty, and farily well consolidated, with no evidence of bedding or lamination in the hand specimen. It effervesces slightly with cold N/10 HCl.

In thin section, this rock is seen to consist mainly of even-grained crystalline carbonate (average diameter 0·05 mm.) together with lesser amounts of quartz, marcasite, glauconite and mica. Foraminifera are present, but nearly all of the carbonate, which constitutes about 87 per cent of the slide, shows no evidence of immediate organic origin. Some of the foraminiferal tests enclose marcasite and a little dark red iron ore, probably haematite—none in this slide encloses glauconite. The origin of the small ovoid grains of glauconite which are present is uncertain—they may have been derived from mica, which is scattered sparingly through the section in the form of green and brown biotite flakes. Nevertheless, a careful search of the slide failed to reveal any mica which is partly changed to glauconite, and there is thus no direct evidence of such a transformation. Tiny patches of what appears to be argillaceous material are scattered sparingly through the rock, but no gradation of these into glauconite was noted.

Many of the aggregates of iron ore (probably marcasite) are composed of grains with a radiating structure, and many of the grains are partly surrounded by faint brown stains of ferric iron. Quartz is present as clear angular grains which form possibly 8 per cent of the whole. The only other mineral noted is an occasional grain of leucoxene.

This rock is a silty crystalline limestone or calcilutite.

Jarosite ?, Base of BR.4

In the hand specimen this rock is soft and friable, and is made up of a pale yellow mineral (which comprises apparently 60 per cent of the whole) black pyrite

and a few grains of a lighter coloured material. The rock does not effervesce with acid.

Microscopically, about 40 per cent of the rock consists of a mineral which has been so impregnated and stained with limonite that it appears opaque and red-brown in reflected light. In places, where limonite staining is not pronounced, the mineral is translucent—it appears yellowish in colour, with high relief, strong birefringence and aggregate Polarization. This mineral may be jarosite, or some mineral closely related to it, but the degree of impregnation with limonite which it has undergone renders microscopic identification uncertain.

Large crystals, many of them of a colourless mineral with weak birefringence and low relief, make up possibly 50 per cent of the rock. This mineral may exhibit multiple twinning, has good cleavage in one direction, and is interleaved with a pale grey or neutral mineral with higher birefringence. The optical properties of the colourless mineral are as follows:

Elongation—negative.
2V—positive, about 65°
R.I.—1·518-1·529 as nearly as can be determined.

These properties show that the colourless mineral is gypsum. Some crystals have a diameter of up to 4 mm; other smaller, perfectly euhedral, crystals are completely enclosed by the mineral, impregnated with limonite.

Associated closely with the gypsum is a pale, colourless to grey flaky mineral with moderate birefringence and relief greater than balsam. This mineral is uniaxial or nearly so, and is optically negative. The extinction of most but not all of these flakes is parallel and the elongation is positive. The mineral is probably alunite. It appears to occur in close association with the gypsum crystals.

About 10 per cent of the rock is made up of pyrite. This is in form of aggregates, many of which have linear borders that seem to have been determined in some measure by the crystallizing power of the gypsum.

This rock is a weathered alunite jarosite (?), gypsum rock.

BR.4

The rock is light grey, argillaceous and friable, with no visible lamination in the hand specimen. It contains occasional fragments of bryozoa and shells together with foraminifera, quartz and a small amount of mica and green glauconite. The rock effervesces with cold N/10 HCl.

Under the microscope, this rock is seen to consist mainly of foraminiferal tests, fragments of hard parts of larger organisms and quartz grains. Also present are pyrite, glauconite, mica, a few sponge spicules and a brownish, earthy base which is difficult to resolve but apparently consists of a very finely-divided quartz, mica, carbonate and clay.

Many of the large carbonate fragments are pale brown and turbid and are probably partly altered to collophane; the abundant foraminiferal tests, some of which are turbid, are generally somewhat clearer in appearance. The outlines of many foraminiferal tests are well defined, and these can be clearly seen acting as hosts to glauconite. In many tests each chamber of the foraminifera is completely filled with green glauconite. Possibly between 5 and 10 per cent of the tests are so filled; the remainder are empty or contain a filler of pale brown, earthy material that shades into pale green. Glauconite was seen which is not enclosed by foraminiferal tests—this seems to grade from dark green glauconite proper to pale brownish material with a greenish tint.

A small proportion—less than 1 per cent of the rock—is made up of pyrite. In some places this mineral partly or wholly fills the chambers of foraminifera, and in other parts of the slide it occurs as isolated grains. Quartz as angular grains with a diameter of 0·05 mm., and a little felspar, probably orthoclase, are the only other minerals present.

The rock is made up in the following proportions: carbonate 68 per cent, pale brown earthy material 21 per cent, quartz 7 per cent, glauconite 2 per cent, pyrite 1 per cent, felspar and mica 1 per cent.

This rock is a silty argillaceous calcarenite.

BR.5

This rock, which is grey and very friable, is made up of shell fragments and tiny foraminiferal tests with a little green glauconite and a few specks of mica. It exhibits no bedding or lamination in the hand specimen. It effervesces with cold N/10 HCl.

Under the microscope, this rock is seen to be composed mainly of foraminiferal tests and other calcareous fragments, angular quartz grains (average diameter 0·06 mm.), argillaceous material, some glauconite, and pyrite. Many of the foraminiferal tests have been well preserved and stand out clearly in thin section; the carbonate of which they are composed is grey and turbid. Other irregularly shaped fragments which range in colour from grey to brown have been determined as the broken portions of shells and echinoid spines. A few colourless sponge spicules are also present. Brown fragments may have been changed from carbonate to collophane Many, but not all, foraminifera contain glauconite; on the other hand, some glauconite can be seen which does not appear to have been enclosed within an organic structure. A few small grains of pyrite can be seen, often concentrated within a foraminiferal test. Carbonate (including collophane) makes up 68 per cent of the whole, quartz about 30 per cent, and glauconite 2 per cent.

This rock is a silty, argillaceous calcarenite.

BR.14

In the hand specimen the rock is grey and friable; foraminifera, flakes of mica and a little black pyrite are clearly visible in an argillaceous base. The rock is not laminated. It effervesces with cold N/10 HCl.

In thin section, this rock is seen to be composed of a base of pale grey-brown material, quartz grains and foraminiferal remains, together with some glauconite, biotite and other minerals. The grey-brown base, as far as can be determined, is made up of argillaceous material, finely-divided quartz, tiny flakes of mica, a little felspar and possibly carbonate; small grains of black iron ore are scattered throughout. In one part of the section the base takes the form of ovoid pellets, whose large and small diameters average respectively 0·28 and 0·15 mm. As the pellets are slightly deeper coloured round the margin than towards the centre, and may be cemented locally by iron ore, their outlines are in places very clearly defined. Some of the pellets contain aggregates of a mineral with low relief and low birefringence which has a radial structure—this is probably chalcedony. It seems likely that these pellets may be a variety of coprolite.

Glauconite is not abundant. Some of it is enclosed within the tests of foraminifera, but much of it shows no trace of any enclosing organism. Not all foraminifera contain glauconite—some appear empty and others contain finely-divided carbonate and argillaceous material. A few small grains of green glauconite can

be observed whose boundaries, even under a magnification of 450, merge imperceptibly into the surrounding argillaceous matrix; this suggests derivation of the glauconite from the finely-divided base. There is a fair abundance of green biotite scattered throughout the slide, but a careful search has failed to reveal any biotite which is definitely in the process of alteration to glauconite.

Angular quartz grains of average diameter 0·05 mm. make up 12 per cent of the rock. Pyrite is fairly abundant—it constitutes perhaps 3 per cent of the whole and occurs as a local cement between coprolite pellets, and as small grains scattered throughout the slide. A few foraminifera are replaced by pyrite. A little black iron ore and some red-brown iron stains are also present.

This rock is a silty, foraminiferal and coprolitic marl.

Hard Band in BR.14

This rock is grey-white and compact, and contains numerous white shell fragments and foraminiferal tests, together with a little green glauconite. It effervesces slightly with N/10 HCl.

Under the microscope, this rock is seen to consist mainly of carbonate made up of fragments of foraminifera and bryozoa and other organic remains in a finely granular, carbonate cement. Most of the organic detritus is slightly turbid and a little is converted to pale brown collophane.

Glauconite, as green ovoid grains, many of which are clearly enclosed within foraminifera, makes up about 1 per cent of the whole. Angular quartz grains, of average diameter 0·1 mm., also make up 1 per cent.

Other minerals present are a few grains of pyrite, a little kaolin and limonite, and some small grains of a brown mineral with high relief and high birefringence, which may be sphene.

The rock is a calcarenite.

Section 9—Between Fisherman's Steps and Bird Rock

FB/4

The rock is grey and friable, and contains small gastropods, foraminiferal tests, green glauconite pellets, a few small quartz grains and some specks of mica. The specimen contains a few very small red-brown patches of limonite, and exhibits no bedding or lamination. It effervesces with cold N/10 HCl.

Under the microscope this rock is seen to consist mainly of carbonate—made up chiefly of shell fragments and foraminiferal tests—together with smaller amounts of glauconite, pyrite, limonite and muscovite. Some of the material of which the foraminiferal tests and shell fragments are composed is grey and turbid though some is pale brown where converted to collophane. A pale grey base, made up probably of very finely-divided mica, carbonate, quartz and clay with limonite and pyrite specks scattered throughout, comprises 15 to 20 per cent of the whole.

Glauconite forms 1 per cent of the rock and much of it is enclosed within foraminiferal tests, many of which have their walls pressed apart or broken. Many grains of glauconite have no enclosing test walls, and careful examination of them has failed to reveal even small portions of test wall fragments. A few small grains when examined under high power magnification (x450) seem to consist of green glauconite cores which merge gradually into the grey argillaceous base. This suggests derivation of at least some of the glauconite from the base. Other grains with fairly well defined boundaries resemble in shape many of the mica flakes which are present. This resemblance is fairly strong where the mineral has the

rough or slightly mammilated surface of glauconite and has practically no double refraction. No definite example of the conversion of biotite can be seen, i.e. there seems to be no example of a grain which is part biotite, part glauconite. This may perhaps be due to the fact that the biotite is green, making any alteration to green glauconite, if present, particularly difficult to recognize in small flakes. Much of the glauconite contains small flakes of mica and tiny quartz grains which could indicate either derivation from the finely divided matrix, or derivation from glauconite which expanded during the process, absorbing surrounding clastics.

An opaque mineral with a metallic lustre and bronze-yellow colour in reflected light which occurs as irregular grains commonly with a radial structure, is probably marcasite. One marcasite aggregate is enclosed within the test of a foraminifera, and some foraminifera and shell fragments have been replaced by the mineral. Almost without exception, marcasite is surrounded by an aureole of red-brown material, apparently carbonate which has been discoloured by iron-rich solutions derived from the marcasite.

Small specks of haematite, making up about 2 per cent of the rock, are scattered uniformly throughout the slide. Angular quartz with an average diameter of only 0·02 mm. represents probably less than 1 per cent. A few small black iron ore grains, occasional flakes of biotite and a little felspar comprise the only other minerals present.

The rock is a silty calcarenite.

FB.3

This rock is medium grained, very friable and light grey. It is made up mainly of shell fragments, foraminiferal tests and quartz grains, with occasional small greenish patches of glauconite. This rock effervesces with cold N/10 HCl.

Under the microscope the rock is seen to consist essentially of grey turbid carbonate probably derived from pre-existing limestone, foraminiferal tests and other organisms, patches of grey-brown, finely-divided cement, angular quartz fragments and pellets of glauconite. The grey-brown matrix, which comprises possibly 7 per cent of the rock, is made up of clay, finely-divided quartz, minute mica flakes and carbonate, the whole cement stained lightly with red-brown iron oxide. Some small irregular patches of pale yellow-green glauconite are scattered throughout the matrix, into which they seem to grade imperceptibly, suggesting they have been derived directly from it. Other glauconite is found as ovoid pellets with a long diameter of up to 1 mm. and a short diameter of up to 0·6 mm. A little glauconite is found in the skeletons of bryozoa and the tests of foraminifera. This glauconite may ccupy all chambers of the foraminiferal test, or only the outer chambers. The walls of some of the tests that contain glauconite have been pressed apart, suggesting that larger grains may once have been similarly encased. However, careful examination of many of these grains has revealed no evidence of fragmentary test walls. The glauconite of this rock ranges in colour between yellow-green and dark yellow-green—probably all varieties show aggregate polarization but this is difficult to see where the birefringence is very low. Double refraction seems to range between very low and fair (apparently second order) but is generally hard to determine because of the masking effect of the colour of the material. Glauconite makes up 2 per cent of the whole.

Angular quartz makes up about 5 per cent of the rock—grains are fairly large and have an average diameter of 0·5 mm.

The rock is a sandy argillaceous calcarenite.

SECTION 12—BETWEEN FISHERMAN'S STEPS AND DEAD MAN'S GULLY

Bed "K"

This rock consists of a white, friable mass of carbonate, iron-stained in patches, which effervesces with cold N/10 HCl.

In thin section, the rock is seen to consist of finely-divided, grey matrix (which is red-brown in places due to iron staining) and angular quartz grains. The matrix may owe its grey colour to the presence of argillaceous impurities and makes up 93 per cent of the rock; quartz grains, with an average diameter of 0·04 mm., make up 3 per cent. No recognizable organic remains are present in this section, the only constituents being felspar, a little chlorite and a few grains of black iron ore.

The rock is a silty marl.

Bed "J"

This rock is grey in patches, but is generally red-brown due to oxidation of the iron content. It is fine-grained, slightly friable, and effervesces slightly with cold N/10 HCl.

Microscopically this rock consists of an iron-stained mass of finely-divided carbonate, probably associated with clay, together with quartz grains and foraminiferal tests. Iron-stained material makes up 80 per cent of the rock; in some places the staining is concentrated in cores which are entirely opaque and are red in reflected light—these cores probably represent haematite. Quartz, as clear, angular grains with an average diameter of 0·04 mm., and a little felspar, constitute 19 per cent of the whole.

A few small patches of glauconite, enclosed within foraminiferal tests, can be seen—other minerals present include muscovite, brown biotite, black iron ore and one grain of tourmaline.

The rock is a silty marl.

Bed "H"

In the hand specimen, the rock is grey, silty and non-friable; on broken surfaces black dentritic aggregates of pyrite are visible. The rock effervesces slightly in cold N/10 HCl.

Under the microscope, the rock is seen to consist of very finely crystalline, somewhat turbid mass of carbonate containing angular quartz grains. Carbonate forms possibly 82 per cent of the whole; quartz grains which have an average diameter of only 0·04 mm. make up about 9 per cent. Pyrite occurs as small grains and dentritic aggregates, many of which are surrounded by an aureole of red-brown iron stains. Pyrite constitutes 8 per cent of the rock. The remainder is made up of a few plagioclase grains, patches of brownish material which are difficult to resolve under the microscope but which seem to consist of chlorite and clay, and rare grains of zircon. One carbonate fragment which probably represents a foraminiferal test, is present.

The rock is a silty calcilutite.

FD.7

In the hand specimen this rock is grey with iron-stained patches; it is aphanitic, fairly friable, and effervesces with cold N/10 HCl.

In thin section the rock is seen to be made up of finely granular, even-grained carbonate with no obvious organic structure, and an average grain diameter of 0·04 mm. Carbonate forms 95 per cent of the rock; angular quartz makes up 3 per cent. A few grains of green glauconitic material, a little pyrite, haematite and leucoxene,

and some small, indefinite patches of brownish material, make up the remainder of the rock. Most haematite grains are surrounded by small red-brown areas of stained carbonate.

The rock is an aphanitic crystalline limestone or calcilutite.

Bed "B" in RP.3

In the hand specimen, this rock appears pale orange-brown due to uniform staining by iron oxide; it is fine-grained, slightly porous, non-friable and is not laminated. It effervesces with cold N/10 HCl. Tiny foraminiferal tests can be seen with difficulty by the naked eye.

Under the microscope, 94 per cent of the rock is seen to be composed of grey, partly iron-stained carbonate; the carbonate is made up of the calcareous skeletons of various organisms including the tests of foraminifera. Some poorly defined patches of turbid grey-brown material within the tests, which cannot be resolved under the microscope, probably represent lithified mud. This material in places has a pale dirty green colour, and is presumably the precursor of glauconite.

Glauconite, together with secondary limonite, forms 5 per cent of the rock. This mineral seems to be almost invariably enclosed within a foraminiferal test, or within the pores of some organic skeletal remains. All stages can be seen in the conversion of glauconite to limonite, as follows:

(1) Pale yellow-green glauconite with aggregate polarisation.
(2) A greenish, brown mineral with masked polarisation colours. This mineral appears dull red-brown in reflected light.
(3) An opaque mineral which is red-brown in reflected light-limonite.

In places tiny grains of pyrite are associated with the glauconite.

Quartz is sparsely distributed throughout the rock in angular grains with an average diameter of only 0·05 mm.—this contrasts with the foraminifera which range up to 0·5 mm. and average about 0·3 mm. Quartz comprises probably less than 1 per cent of the whole.

This rock is a glauconitic calcarenite.

Bed "A" in RP.1

The rock is grey, slightly iron-stained in places and somewhat friable. It shows no trace of bedding or lamination. Green glauconite, quartz grains and foraminiferal remains can be seen with the naked eye. The specimen effervesces with cold N/10 HCl.

Under the microscope, this rock appears somewhat coarser than those described previously. It consists mainly of carbonate (95 per cent) and angular quartz grains. The carbonate is generally grey and turbid, and is made up of broken fragments perhaps of pre-existing limestone, many with good cleavage, and abundant clearly defined foraminiferal tests. Irregular clots of a yellowish-green mineral with aggregate polarisation, which is partly converted to limonite, represent glauconite. These make up about 1 per cent of the rock, and are usually found enclosed in foraminiferal tests. A few patches of grey-green material which are difficult to resolve under the microscope, probably consist of finely divided carbonate, clay and mica.

The quartz grains, which are notably angular, have an average diameter of 1 mm.; innumerable small cavities, generally less than 0·01 mm. in diameter, are present. These cavities contain a gas-liquid mixture, the fluid nature of which is clearly demonstrated by small bubbles which can be seen moving from side to side of their enclosure.

This rock is a calcarenite.

Section 3—Between Soapy Rocks and Point Roadknight, Anglesea

W.98

The rock has a grey, slightly vesicular matrix containing angular fragments of white or pale green, cryptocrystalline shards and larger fragments which are embedded in a brown, amorphous, isotropic matrix. The brown matrix probably represents a mixture of ash, argillaceous matter and glassy material; it commonly contains angular fragments of quartz up to 0·1 mm. in diameter and crystallites of plagioclase.

The pale, cloudy, cryptocrystalline fragments in some cases contain numerous incipient plagioclase crystals, which may be arranged either as a network, or in a linear manner suggestive of flow structure. Other fragments contain aggregates of larger, euhedral to subhedral plagioclase crystals which may attain a length of 2 mm.—this plagioclase is usually of the variety labradorite. Spherulitic aggregates of chalcedony are also present in a few places. The larger cryptocrystalline masses and shards are commonly surrounded by a brown aureole which is appreciably darker than the majority of the brown matrix.

Also present in the rock are a few small grains of a green non-pleochroic mineral which is either isotropic or weakly double-refracting. Grains of black iron ore and rare pyrite are scattered throughout.

This rock is a fine volcanic breccia containing mud fragments.

W.12

A sample of a soft yellow mineral (W.12) thought to be jarosite, was roughly analysed in 1947 by E. R. Segnit of the Cement Section, C.S.I.R.O., Fisherman's Bend, Melbourne. His results are as follow:

SiO_2	23·9
Fe_2O_3	16·5
Al_2O_3	6·2
CaO	0·9
MgO	n.d
H_2O at 113	16·3
H_2O at 113	7·5
Na_2O	5·1
K_2O	nil
SO_3	21·1
	97·5
Insoluble matter	26·9%

In explanation of his results, Segnit states that the mineral appears to be natrojarosite, mixed with earthy matter. He thinks the lime may be present as carbonate, and that the result for sulphate may be too low. No potash could be detected with the flame photometer. The insoluble residue is considered to be chiefly quartz.

Section 19—Airey's Inlet

A.1 (Specimen 1)

In the hand specimen the rock has an overall grey-green colour; it is slightly friable, fairly weathered and somewhat vesicular. Few serpentinous relicts of olivine phenocrysts together with abundant white, angular grains of tridymite are set in the dark, fine-grained groundmass. This sample is in the form of a small cobble, and apparently forms part of a volcanic agglomerate—a small portion of the grey matrix of the agglomerate is attached to the cobble.

Under the microscope, the rock is porphyritic with completely altered olivine phenocrysts of average diameter 1 mm. in a fine-grained groundmass. Tridymite is abundant as a colourless, clear mineral which apparently occupies cavities within the rock.

The presence of olivine phenocrysts in the original rock can be inferred from the characteristic, generally euhedral serpentinous pseudomorphs which can be seen. The serpentine, which ranges from reddish-yellow to yellow-green, is made up of two varieties. One variety, the commoner, is lamellar and non-fibrous and probably represents bowlingite; the other occurs as cross-fibre veinlets with pronounced pleochroism from pale green to darker yellow-green or brown—this is probably xylotile. The two minerals are intimately associated. In places, however, the phenocrysts have altered to pale green antigorite.

The groundmass consists essentially of plagioclase, pyroxene and serpentine. Plagioclase occurs as a network of lathes having a composition which may be designated $Ab_{38}An_{62}$.

The average length of these lathes is 0·1 mm. Pyroxene is present as smaller, subhedral, purplish, faintly pleochroic grains which strongly resemble titan-augite and show incipient alteration to pale green bastite. Black iron ore occurs as minute grains and locally as a network of minute lathes. No volcanic glass can be seen, but this may have been the precursor of much of the abundant, pale-green serpentine (probably antigorite) which fills the interstices between the felspar lathes.

Tridymite, which seems to occupy cavities in the groundmass, occurs as angular aggregates; many of these have irregular outlines but are oval in general shape. The maximum diameter of these aggregates commonly approaches 2 mm. The mineral is colourless, has poor relief with n=balsam, very low birefringence and is characterized by abundant wedge-shaped twins. Some of the aggregates have a tile structure when observed under crossed nicols. Interference figures can be obtained on some of the larger crystals, and indicate a positive 2V of 30° to 40°.

The composition of the rock, estimated visually, is as follows:

Groundmass	75%
(Serpentine, 39%; plagioclase, 16%)	
(augite, 10%; magnetite, 10%)	
Tridymite	22%
Serpentine pseudomorphs after olivine	3%

The rock is a serpentinised olivine basalt containing pockets of tridymite, probably as fillings of what were once vesicles. The specimen consists of a small cobble embedded in the matrix of a volcanic agglomerate.

A.1 (Specimen 2)

The hand specimen is grey, friable and unlaminated; it consists mainly of soft, pale brown or grey material together with chalcedony and opal. The rock is apparently the tuffaceous matrix of a volcanic agglomerate.

This rock, which is light grey in the hand specimen, assumes an overall greenish colour when cooked in balsam preparatory to making a thin section. Under the microscope, it is seen to consist mainly of fairly uniform, green, non-pleochroic material which is isotropic or weakly double refracting, and has a low relief with n slightly greater than balsam. The material shows its greatest tendency towards weak double refraction in places where the colour is very pale green or yellowish. It is not certain what the green matrix of this rock represents; it may be a variety of the mineraloid palagonite, which is a hydrogel formed by the alteration of basaltic glass.

Numerous spherulites, generally outlined by a brown or green border, and commonly elongated in a constant direction, are scattered through the rock. The spherulites seem to be composed of two minerals. One variety consists of a colourless fibrous mineral with low relief and weak double refraction which resembles chalcedony, and the other variety is made up radiating fibres of a brown pleochroic mineral with fair birefringence which may be the serpentine xylotile. A few chalcedonic spherulites attain a diameter of 0·6 mm.

Remnants of euhedral crystals, probably of some ferromagnesian mineral, are present; these are entirely replaced by brown, pleochroic, radial aggregates of xylotile. Chalcedony and opal are common and make up probably 15 per cent of the slide. The chalcedony, which is colourless, occurs in what appear to be colloform crusts which have been infilled with grey, isotropic opal. Euhedral to subhedral crystals of labradorite attain in places a length of 0·5 mm. and are present either as aggregates or individuals.

The rock is the matrix of a volcanic agglomerate.

Note on the Origin of Glauconite in the Jan Juc Formation

In thin section, glauconite from the Janjukian type section of Victoria ranges from pale yellow-green to almost apple-green; it has aggregate polarisation, and its birefringence is generally masked by the original colour of the grain. Pellets and grains of the mineral are commonly heterogeneous, and may contain fragments of quartz, mica and various iron ores. The heterogeneous nature of the glauconite, together with its aggregate polarisation, have made almost impossible an accurate determination of the three refractive indices which, however, lie between 1,575 and 1,603. These figures are lower than those usually quoted (Winchell, 1946; and Schneider, 1927), and fall between those given for the Lakes Entrance glauconite and the low index glauconite from South Australia (Dallwitz, 1948).

Glauconite from the Janjukian samples is not constant in optical character, but apparently represents stages in the transformation of some pre-glauconitic progenitor to true glauconite. All glauconitic materials show a marked tendency to alteration to limonite, and the following stages can be seen:

(1) Green glauconite with aggregate polarisation.
(2) A brown mineral with a greenish tint, which has strongly masked birefringence. This mineral appears dull red-brown in reflected light.
(3) An opaque mineral-limonite which is red-brown in reflected light and which may be surrounded by stains of similar colour.

Glauconite from these samples may be broadly divided into two classes as follows:

(1) Glauconite which is enclosed within the tests of foraminifera, or within cavities in other organisms with hard skeletons, or glauconite which was once clearly enclosed by some organic covering. The glauconite may completely fill each chamber of a foraminifera, or may occupy only the outer chambers. Many foraminifera containing glauconite appear in thin section as completely preserved and well-defined tests, where others are represented by fragments of broken test walls.
(2) Glauconite grains which are not enclosed within the hard framework of any organism, and some which may not have been enclosed during any stage of its formation. In this category is included glauconite as oval pellets, glauconite with fairly irregular shape but clearly defined boundaries, and glauconite with indefinite boundaries which seem to grade

> imperceptibly into the surrounding argillaceous material. This latter, poorly defined glauconite, usually occurs as small patches which are scattered rather sparingly through the rock; they are best observed and described under high magnification (× 450).

Galliher (1935) has shown conclusively that glauconite in Monterey Bay, California, has formed from brown and green biotite. Glauconite forms around the edges of the flake, and by working in toward the centre, slowly converts the whole biotite grain. It also attacks biotite along the cleavage, causing the flakes to split slowly apart. With glauconitization comes a great increase in volume, so that, as the flakes are pushed apart, the whole grain assumes a "concertina" structure. Of 800-1,000 grains which Galliher described from Monterey Bay, he noted only one which was enclosed within a foraminifera.

Shepard (1948), noting that glauconite is an indicator of slow deposition, states that, whatever its origin, it is quite certainly an indication of the failure of sediments to cover the deposit during the time of their alteration. As the mineral is found in abundance in the tests of foraminifera, he is inclined to the view that biotite may not be its most important source. Both Shepard and Galliher refer to the pioneer work of Murray and Renard (1891), who emphasized the importance of the alteration of mud in foraminiferal tests to give glauconite. Murray and Renard observed transitions from yellowish-brown mud to glauconite, but believed it improbable that any glauconite was formed from mud in the free state, that is, mud which was not enclosed within foraminifera. Galliher explains the occurrence of glauconite within broken foraminiferal shells as being due to small flakes of biotite which have been sifted into foraminifera, and which have undergone considerable expansion during their transformation into glauconite. This hypothesis does not seem to explain satisfactorily numerous examples of coiled tests which are completely filled with glauconite, and which have both the outer walls and the inner walls separating the chambers, perfectly preserved. Galliher states that, in many cases, the expansion and growth of glauconite as it forms from biotite, causes the final product to assume shapes superficially resembling the casts of foraminifera.

Takahashi and Yoki (1929) have described stages in the formation of glauconite from grey, coprolitic mud. Under high magnification the grey mud is revealed as a heterogeneous complex consisting of extremely fine fragments of quartz and felspar with a dark yellow or brownish, argillaceous matrix.

Biotite found in samples from the Janjukian of Victoria is mainly green, which renders difficult any investigation into its possible decomposition to green glauconite. Careful searching under high magnification has failed to reveal any grain with a core of biotite surrounded by a periphery of glauconite. Furthermore, no evidence of the "concertina" structure of Galliher has been seen. At the same time, some pale green glauconite grains with a mamillated surface, and with well-defined boundaries, resemble adjacent biotite flakes in shape. These pale green grains have a very low birefringence, and may perhaps have been derived from biotite. Thus although no direct evidence of the conversion of biotite to glauconite can be presented, it seems not impossible that a little at least of the glauconite may have come from this source.

Glauconite which is present as occasional, small, poorly defined patches which appear to grade imperceptibly into the surrounding pale, yellow-brown, argillaceous base, is probably not secondary after mica. The so-called argillaceous or muddy matrix is invariably difficult to resolve into its components under the microscope. It generally seems to be made up of yellow, brown or grey clay and finely-divided quartz, together with mica and possibly a little felspar and carbonate. Minute

grains of pyrite and black iron ore may be abundant locally, and the whole may be stained to a varying degree by iron oxide. It should be borne in mind that the small glauconitic patches found in this base may have been formed initially within foraminifera, and may have been subsequently washed out of the tests or otherwise dispersed. Nevertheless, the lack of definition of some of the boundaries of the glauconite grains suggests that the mineral formed as a core which has slowly grown outward by some process of glauconitization. If so, it must be assumed that the argillaceous matrix itself was the precursor of the glauconite; the heterogeneous nature of much of the glauconite, which commonly contains small grains of mica, quartz and iron ore, strengthens this view.

Some glauconite, after concentration and separation from the crushed rock by panning, appears as grains which resemble very strongly the internal casts of foraminifera. When mounted in liquid and studied under the microscope, many grains show no evidence of a surrounding test well. It is not certain what process has removed the wall. Miss Crespin has shown the writer several glauconite casts of foraminifera from the Upper Cretaceous of the north-west of Western Australia; some of these are partly surrounded by test walls which seem to be peeling off. If the walls have been removed during transportation along the sea floor, it is difficult to explain the perfectly preserved shapes of the glauconite surfaces. It is unlikely that the walls themselves have been glauconitized, for in some cases sections of pellets which have no outer wall contain clearly preserved inner walls which once separated the individual chambers of the foraminifera. It is not generally thought that calcareous test walls are prone to alteration into glauconite. The walls may, perhaps, have been pushed apart by the expansion of the argillaceous material during glauconitization, and may then have been removed; any such expansion must necessarily have been slight, for the final product is commonly a perfect internal cast of the test.

Ovoid grains without surrounding walls or internal subdividing walls may have been formed within the test of a single-chambered organism. On the other hand, in view of the apparently coprolitic nature of some of the mud in sample BR.4, it is possible that a little of this glauconite represents coprolite which has been transformed.

The origin of glauconite has been the subject of many interpretations. It has been described by different authors as a mineral which is secondary after mica, coprolitic pellets and mud enclosed within foraminifera. A little glauconite from the Janjukian type section of Victoria may, perhaps, have been derived from mica, but much has probably come from mud, both inside and possibly outside foraminifera. Where mud is converted to glauconite, it seems that an environment involving some form of imprisonment in the organic structure is very favourable, but perhaps not always necessary. It is of interest that Murray and Renard (1891) believed decaying organic matter enclosed within the tests played a large part in the transformation of mud to glauconite, and Schneider (1927) also postulated the necessity of an environment involving organic matter.

It is tentatively suggested that, on the basis of origin, at least two classes of glauconite may be recognized—glauconite formed from mica and glauconite formed from mud. It is further suggested that the refining or sieving undergone when mud is filtered into the chambers of foraminifera, or is passed through the digestive tracts of mud-eating organisms, together with the subsequent compaction it undergoes in each case, favours the formation of glauconite. The mineral has been described above occurring as small patches which have no obvious relationship to any organism. Thus, unless it can be demonstrated that the addition of some

organic compound is a necessary prerequisite to the formation of glauconite, there seems no conclusive reason to assume that free mud, suitably refined and compressed by some means during the normal process of slow sedimentation, can not be similarly transformed.

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CURVATURE-SIZE RELATIONSHIPS OF PORT CAMPBELL AUSTRALITES, VICTORIA

By GEORGE BAKER, M.Sc.

[Read 11 November 1954]

Abstract

Statistical studies, utilizing frequency polygons and scatter diagrams, of the relationships between size of well-preserved australites from Port Campbell, Victoria, and radii of curvature of their posterior and anterior surfaces, result in the conclusion that they represent secondary modifications of a few primary forms of extraterrestrial glass. Primary shapes consisted principally of spheres, which did not rotate, and a proportion of spheroids, dumb-bells and apioids which are fundamentally forms of revolution. The secondary shapes possessed by australites were formed from these few primary shapes which entered the earth's atmosphere as non-rotating, cold bodies. Buttons, lenses and round cores arose from primary spheres. Ovals, boats, canoes, dumb-bells, teardrops and elongated cores developed from primary spheroids, dumb-bells and apioids. The secondary shapes were sculptured in the earth's atmosphere by processes of ablation, thin-film fusion-stripping and skin friction operating upon forward surfaces at ultra-supersonic speeds of earthward flight.

PART I—ROUND FORMS

Introduction

Among nearly 1,500 australites discovered during the past twenty years in the Port Campbell district of south-western Victoria, 571 complete or nearly complete forms are well preserved and suited to the accurate determination of depth and diameter and of arcs and radii of curvature of their anterior and posterior surfaces respectively. For the purposes of curvature-size relationships, the Port Campbell australites have been treated in two principal groups—(i) Round Forms, and (ii) Elongated Forms. The percentages of the various round forms of australites dealt with in Part I of this study are shown in Table 1.

TABLE 1

Group	Shape Type	Numbers of Specimens	Percentage of total number of the forms measured	
ROUND FORMS	Buttons	295	51·7	70·9%
	Hollow buttons	4	0·7	
	Round discs and round plates	15	2·5	
	Round bowls	5	0·9	
	Lenses	64	11·2	
	Round cores	22	3·9	
ELONGATED FORMS	Ovals, boats, teardrops, dumb-bells, etc.	166		29·1%

The shape terminology is based upon Fenner's (1940, p. 312) classification of australites.

This paper (Part I) is concerned with (i) the Round Forms of australites, of which there are 405 well-preserved specimens, constituting nearly 71% of the total

of all forms suited to accurate measurement. The term "Round Forms" is applied here to those australites that possess a circular outline in plan, i.e., when viewed along the polar directions the equatorial outline is circular.

The several types of the round forms of australites are:

(a) Buttons—with flanges.
(b) Hollow buttons—with internal cavities.
(c) Lenses—with rim but no flange.
(d) Round cores—with flaked equatorial zones and never flanged.
(e) Round discs and round plates—flat, thin forms.
(f) Round bowls—posterior and anterior surfaces curved in the same sense, never flanged.

There are statistically sufficient numbers of specimens for significance in each of types (a), (c) and (d). By virtue of their excellent state of preservation, the Port Campbell australites lend themselves especially well to a detailed study of the curvature of their two surfaces—(1) the primary posterior surface and (2) the secondarily developed anterior surface. The radii of curvature determined for these two surfaces on over 400 round forms of the Port Campbell australites are herein compared with one another and with the measured values of depth and diameter and of the intercepts of the diameter line upon the depth line (*cf.* Fig. 3). The comparisons are made by means of frequency polygons and scatter diagrams. All the values of the various measurements are given in millimetres.

Abbreviations used in the text are as follows:

R_F—radius of curvature of anterior surface.

R_B—radius of curvature of posterior surface.

De—true depth(or thickness) as measured between the front and back poles of the anterior and posterior surfaces respectively (*cf.* Fig. 3).

Di—true diameter (the radical line), as measured by construction, between the points of intersection of two coaxal circles, portions of which represent the arcs of curvature of anterior and posterior surfaces respectively (*cf.* Fig. 3).

OM—distance from front pole (M—on anterior surface) to centre of radical line (diameter).

ON—distance from back pole (N—on posterior surface) to centre of radical line (diameter).

OM and ON represent the intercepts on the depth line (MN) cut off by the radical line (KL) as indicated in Fig. 3, and their summation is thus equal to the true depth, so that OM + ON = MN = De.

Curvature of Surfaces

Sketch diagrams of the types of round forms measured are shown in Fig. 1.

In Fig. 1, the sketches of the normal flanged button, the small flanged button, the lens and the round core are depicted in three-dimensional aspects. Horizontal planes (diagonal shading) are circular; vertical planes (solid black) have the same outlines as those drawn in the plane of the paper. Sectional outlines of flanges are shown in the equatorial regions of the normal and small flanged buttons, but in order that the core (or body) portions of the buttons could be compared and contrasted with the lens type, flanges have been omitted from both diameter measurements and from radii and arc of curvature considerations. Measurements of the curvature of the surfaces of round bowls and of round discs (or round plates)

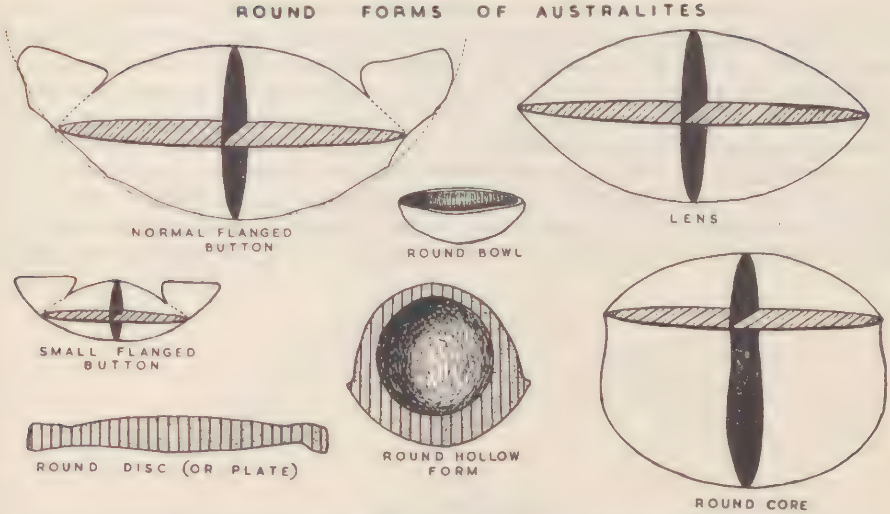


FIG. 1.—Sketch diagrams of round forms of Port Campbell australites. In each sketch the posterior surface of the form is at the top. All enlarged 2·75 times except the round hollow form, which is 0·5 times.

had little statistical significance, in view of the small populations among these types.

Method of Obtaining Arcs and Radii of Curvature

Each suitably preserved australite was placed in the focus of a horizontal beam of light and its silhouette traced at 5·5 magnifications. On the outlines so produced, three chords were drawn for each of the two surfaces (anterior and posterior surfaces respectively), and each chord was bisected as indicated in Fig. 2. Normals to the chords through the points of bisection, mostly met at three-point intersections, as in Fig. 2; a few met to produce a small triangle of error. With the points of intersection of the bisectrices as foci (Y and Z in Fig. 2), circles were constructed about the curved anterior and posterior surfaces, and in most examples showed almost perfect coincidence with the curvature of these surfaces. Minor irregularities caused by the presence of bubble pits on posterior surfaces and flow ridges on anterior surfaces were smoothed out in the silhouette tracings. Each australite was rotated in the beam of light through 45° and 90° about the polar axis, and in each position the arc of curvature of each surface matched the original silhouette tracing, indicating the maintenance of similar curvature all over the anterior surface, and similar curvature all over the posterior surface.

The relationships of the curvature of anterior and posterior surfaces respectively vary somewhat from form to form according as to whether the back or front pole is situated nearer to the centre of the radical line (= diameter line). A characteristic relationship is indicated in Fig. 3.

In Fig. 3, NM is the depth line joining the back pole on the posterior surface and the front pole on the anterior surface. KL is the radical line which joins the points of intersection of the two coaxal circles circumscribed one about the posterior surface and the other about the anterior surface. One of these circles

passes through the back pole (N) and the other passes through the front pole (M). These circles, constructed about each arc of curvature obtained in the silhouette tracings, were shown to be coaxal by virtue of the depth line NM being normal to the radical line, and the foci (Y and Z) of the arcs of curvature were thus collinear, being located on the depth line or its extension beyond the limits of the outline of each form as determined by the construction shown in Fig. 2. The arc of curvature KML in Fig. 3 provides the radius of curvature ($zM = R_F$) of the secondarily developed anterior surface in australites, while KNL provides the radius of curvature ($yN = R_B$) of the remnant portion of the primary posterior surface. The lines KL and NM in the construction (Fig. 3) provide measures of

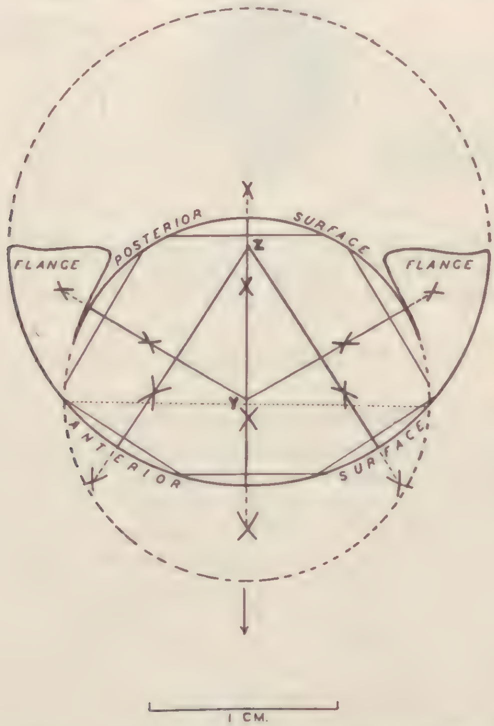


FIG. 2.—Actual trace of silhouette of button-shaped Port Campbell australite, illustrating method of determining radii of curvature, depth and diameter of a form having $R_F = 12 \cdot 5$ mm., $R_B = 9 \cdot 5$ mm., De = 14·0 mm., Di (ex-flange) = 19·0 mm., OM = 4·0 mm., and ON = 10·0 mm. (All measurements taken to the nearest 0·5 mm.)

the true diameter and true depth for an australite, when the measured values are reduced according to the reduction factor appertaining to the particular enlargement of the silhouette tracing. The intercept ON of the radical line upon the depth line (Fig. 3) provides a measure of the distance of the back pole (N) from the centre (O) of the radical line (KL), while the OM intercept provides a measure of the distance away of the front pole (M). Since the radical line is contained in a circular plane and (O) is the mid-point in this plane, it follows that the

intercepts ON and OM represent the distances of back and front poles respectively from the centre of the circular horizontal plane. It will be shown later that this plane is not always a plane of symmetry, hence (O), the mid-point of the horizontal plane, does not coincide with the centre of the australite, unless ON and OM have the same values. It will be seen from the following frequency polygons and scatter diagrams depicting ON and OM values, and the ratios between these values, that the distances between the back and front poles and the centre (O) of the circular horizontal plane containing KL vary a little from group to group and sometimes from form to form in the same group, but a large number of forms have ON and OM equal in amount. Hence the point (O) is frequently the central point of the australite.

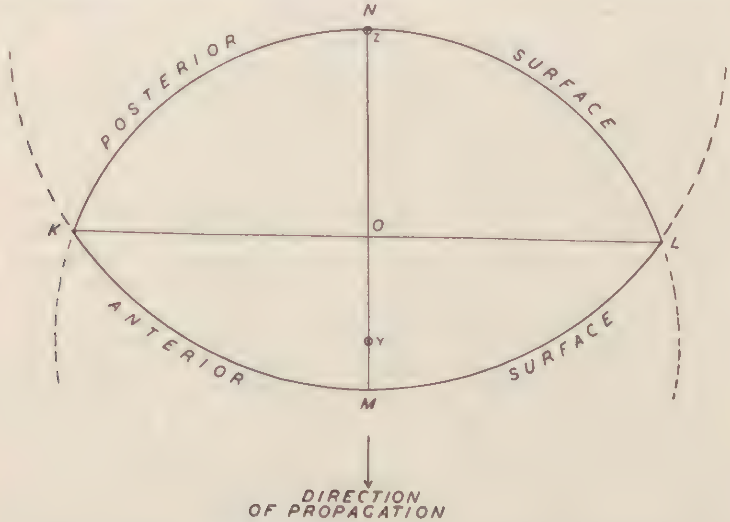


FIG. 3.—Sketch showing relationship of curvature of anterior and posterior surfaces of a typical round form of the Port Campbell australites.

Standardization of Measurements and Comparisons

As indicated above, measurements of the secondary flange structure in the equatorial regions of flanged australites have been purposely omitted from R_F and Di considerations. There are two main reasons for this procedure. The first is that all flanges do not possess the same arc of curvature as the body portions to which they are attached. One and the same arc of curvature is indicated for the anterior surface of flange and body alike in Fig. 2, but such examples are not universal, as there exist several button-shaped forms in which the anterior surface of the flange tends to be flatter and several where it is steeper than that of the body portion. A second reason is that in comparisons between flanged buttons and the non-flanged lenses and the non-flanged round cores, the flange structures of the buttons have to be omitted from consideration, otherwise errors in diameter relationships would arise. For example, the inclusion of the flange width in overall diameter measurements of a flanged button could provide a greater value than for a non-flanged lens, and yet the diameter of the lens might be greater than that of the comparable body portion of the flanged button. It is thus important to

standardize this factor for the purposes of radii of curvature and diameter determinations. Since it is impossible, by virtue of their very nature, to directly measure the diameters of the body portions of buttons possessing complete or nearly complete attached flanges (unless resort is made to needlessly destroying such complete forms by fracturing away the flange), diameter measurements of the body portions were obtained from the silhouette tracings by construction (*cf*. Figs. 2 and 3). Such measurements are accurate to the nearest 0·5 mm.

The significance of excluding the flange structures from comparative studies involving diameter and radii of curvature measurements can be gained from the following remarks. In many large collections of australites that have been described and classified there is often a marked preponderance of lens-shaped forms over button-shaped forms. There is little doubt that this state of affairs arises from the much-abraded condition of most specimens in such collections. On the other hand, the australites found in the Port Campbell district come from a region where abrasion processes have been at a minimum, and moreover, only the best-preserved specimens have been utilized in curvature-size studies. Hence button-shaped australites are more numerous than lens-shaped australites. The original parentage of many broken, etched and partially abraded round forms of australites can often be detected by searching their surfaces for traces of remnant structures such as minute flange remnants, or the occurrence of the smooth annular areas known as "flange bands" which are sometimes preserved in the equatorial regions of posterior surfaces and mark the sites of attachment of pre-existing flanges. Such remnants point to an original button parentage among the round forms of australites, and hence such specimens can be safely utilized for diameter and radii of curvature measurements in the button-shaped types of australites. The complete removal of vestiges of flange structures by excessive weathering would lead to classification with the non-flanged lens group, resulting in an undue weighting of numbers among the lens type australite population. This in itself, however, may not be a serious factor in the curvature-size relationships as between buttons and lenses, since it is shown in the following frequency polygons and scatter diagrams that there is a close similarity between the body portions of button-shaped australites and the lens-shaped australites. It does, however, explain why collections composed of well-preserved specimens contain a higher proportion of buttons with flanges, while collections composed of strongly abraded specimens contain a higher proportion of the non-flanged lenses. This factor would become important in comparing curvature-size relationships for round forms from different districts.

Among the Port Campbell australites selected for curvature-size studies, every precaution has been taken to prevent over-weighting of numbers in any particular shape type that might arise from the wrong classification of somewhat abraded forms. This aim has been greatly aided by the excellent state of preservation of most specimens in the collection, and the omission of all of doubtful classification. Round forms with flanges are thus definitely button-shaped types. Round forms resembling the body portions of buttons, possessing rims only and no traces whatsoever of flange remnants, are classified as lenses, developed as such by a process of atmospheric flight-shaping, wherein all traces of flange, if ever developed, had already been removed by ablation and fusion-stripping during high-speed traverse through the earth's atmosphere.

It has been found from the constructions typified by Figs. 2 and 3 that of the two respective coaxal circles circumscribed about the arcs of curvature of the anterior and posterior surfaces, one coaxal circle fits around the front polar regions

TABLE 2

Ranges in Curvature-Size Measurements of 405 Round Forms of the Port Campbell Australites

Shape Type	Percent of Round Forms	R_F (mm.)	R_B (mm.)	Ratio $R_B : R_F$	Diameter (mm.) (Di)	Depth (mm.) (De)	Ratio De : Di	Intercept OM (mm.)	Intercept ON (mm.)	Ratio OM : ON
Buttons ..	73·0	5·0–18·5	2·0–24·5	1 : 0·36– 1 : 4·00	2·5–33·0	2·5–19·5	1 : 0·56– 1 : 3·30	0·5–12·5	1·0–10·0	1 : 0·10– 1 : 5·00
Hollow Buttons ..	1·0	12·0–18·5	10·0–17·5	1 : 0·91– 1 : 1·60	17·5–30·0	16·0–28·0	1 : 0·93– 1 : 1·50	2·5–23·0	7·0–20·0	1 : 0·30– 1 : 6·00
Round discs and Round Plates	3·5	5·0–28·0	3·5 →	1 : 1– 1 : 4·13	6·5–14·0	1·0–2·5	1 : 2·80– 1 : 7·00	0·25–1·0	0·75–2·0	1 : 1– 1 : 4
Round bowls	1·0	4·5–9·0	49·0 →	—	9·0–16·5	1·0–4·5	1 : 2·00– 1 : 9·50	—	—	—
Lenses ..	16·0	5·5–13·0	4·5–17·5	1 : 0·40– 1 : 1·90	8·0–19·0	3·5–12·5	1 : 1·50– 1 : 2·90	1·0–4·5	1·0–8·0	1 : 0·35– 1 : 2·50
Round Cores	5·5	8·0–20·5	11·0–36·0	1 : 0·42– 1 : 1·20	14·5–34·0	10·5–24·5	1 : 1·20– 1 : 2·30	5·0–13·5	2·5–14·5	1 : 0·22– 1 : 1·45

$\rightarrow = \infty$, and as in round bowls, curvature is in a negative sense.

and across the tops of the flow ridges nearest the polar regions on the anterior surface (*cf.* sketch of normal flanged button in Fig. 1). The other coaxal circle fits across the tops of the walls of surface bubble pits exposed on the posterior surface. All the arcs of curvature constructed about the anterior and posterior surfaces of the 405 round forms studied were standardized on this basis.

On flanged forms of australites it can be observed (*cf.* Fig. 2) that the posterior coaxal circle intersects the anterior coaxal circle in the region of the line of union between flange and body portions; moreover, the arc of curvature of the line of union between these two structures is identical in degree and position with that of the constructed posterior coaxal circle.

The true diameters of round cores (sometimes called "bungs"), such as the specimen depicted in sketch form in Fig. 1, which possesses a flaked equatorial zone (recessed region below horizontal plane in sketch), were all measured from graphical constructions based on silhouette tracings. The distance between the points of intersection of coaxal circles described around anterior and posterior surfaces respectively was taken as the true diameter of each round core form prior to the development of the flaked equatorial zone by fusion-stripping during rapid non-rotational flight through the earth's atmosphere. These points of intersection thus lie outside the silhouette tracings of such forms.

Radii of Curvature, Depth, Diameter and Intercept (OM and ON) Values

The measured values of the radii of curvature of anterior and posterior surfaces, of depths and of diameters for the round forms of australites from the Port Campbell district are summarized in Tables 2 and 3, according to the various shape types represented. Ranges in these values are listed in Table 2; average values have been calculated and are listed in Table 3. The calculated average values are compared in Table 4 with the model values obtained from the construction of frequency polygons.

Tables 2 to 4 show the general trends in the variations of R_F, R_B, Di, De, OM and ON from shape type to shape type among round forms of australites from the Port Campbell district. There are marked increases in the values of all the measurements from round discs and plates, through lenses and buttons to round cores and hollow buttons. Ranges and average values for the several curvature and size measurements among the button type of australite include both the normal and the small flanged buttons. With increased radii of curvature and hence flattening of the arc of curvature of their surfaces, the smaller of the small flanged buttons merge into the shape type composed of the round discs and plates.

Radius of curvature values for the posterior surfaces (R_B in Tables 2 and 3) of the round discs and round bowls range up to infinity as certain forms attain virtual flatness of this surface. The radius of curvature values of the posterior surface (R_B) of some round bowls include a few specimens in which the arcs of curvature of the posterior surfaces are directed in the same sense as that of their anterior surfaces. Such forms, which are thin (approximately 1 mm.) have passed beyond the flattened condition and have become bent backwards while softened.

The ratios between the pairs of measurements (a) R_F and R_B, (b) Di and De, and (c) OM and ON, are listed in Tables 2, 3 and 4. In these pairs of measurements, R_B, De and OM were retained at unity in calculating the ratios. Comparisons of these ratios from shape type to shape type reveal certain similarities and a few marked variations. Thus the calculated average ratio of R_B to R_F is very

TABLE 3

Average Values of Curvature-Size Measurements of 405 Round Forms of the Port Campbell Australites.

Shape Type	Percent of RoundForms	R_F (mm.)	R_B (mm.)	Ratio $R_B : R_F$	Diameter (mm.) (Di)	Depth (mm.) (De)	Ratio De : Di	Intercept OM (mm.)	Intercept ON (mm.)	Ratio OM : ON
Buttons ..	73·0	9·5	8·5	1 : 1·20	14·0	7·5	1 : 1·91	3·5	4·5	1 : 1·42
Hollow Buttons ..	1·0	15·5	13·5	1 : 1·20	24·0	22·0	1 : 1	10·0	12·0	1 : 2·8
Round discs and Round Plates	3·5	12·0	8·0	1 : 2·20	9·5	2·0	1 : 5	0·5	1·5	1 : 2·7
Round bowls	1·0	6·5	—	1 : 0·13 (1 sp.)	11·0	3·0	1 : 5	2·5 (1 sp.)	0·5 (1 sp.)	1 : 0·2 (1 sp.)
Lenses ..	16·0	8·5	8·0	1 : 1·12	12·0	6·0	1 : 2·1	3·0	3·0	1 : 1·2
Round Cores	5·5	14·0	17·0	1 : 0·86	24·5	15·5	1 : 1·7	9·0	6·0	1 : 0·7

similar in buttons, hollow buttons and lenses, but markedly higher in the round discs, lower among the round cores and round bowls. The ratio of De to Di shows significant variations from type to type among the various shapes, while the ratio of the intercepts OM to ON shows marked differences from shape type to shape type. However, when these ratios are compared in terms of the modes of the frequency polygons (Table 4), minor variations are smoothed out between the more densely populated shape types of the buttons, lenses and cores. This is because the frequency polygons are based upon measurements taken to the nearest 0·5 mm., whereas the calculated average values of the ratios are based on determinations taken to the nearest 0·1 mm. (as obtained by applying the reduction factor in connection with measurements derived from the silhouette constructions).

Table 4 reveals unit ratio for $R_B : R_F$ relationships, a two to one ratio for Di : De relationships, and significant variations from shape to shape for OM : ON relationships. The variations in OM : ON relationships signify that in button-shaped australites the front pole is more usually a little nearer to the centre of the horizontal plane than is the back pole, while lenses are more consistently lenticular, bilaterally symmetrical objects, with front and back poles approximately equally spaced on either side of the centre of such forms, the centre thus being contained in a horizontal plane of symmetry. In round cores, on the other hand, the front pole is usually spaced twice as remote from the centre of the horizontal plane than is the back pole, and the horizontal plane is not a plane of symmetry.

These variations in OM : ON relationships, reflecting as they do variations in the spacing of back and front poles from the centre of the horizontal plane, can be explained in terms of varying degrees of reduction of original primary spheres, or spheroids approximating to spheres, of different original sizes. Reduction resulted from ablation and fusion stripping to different degrees during rapid earthward, non-rotary transit through the atmosphere. Many of the secondary resultant round cores indicate least reduction of the primary form on this basis, while secondary resultant flanged buttons and lenses indicate far greater amounts of ablation of the original primary forms.

Frequency Polygons and Scatter Diagrams

In the following frequency polygons depicting the relationships of the various measurements to the numbers of forms in each particular shape type having the same values of these measurements, only the button, lens and round core types can be satisfactorily illustrated, for in each of these three shape types among the round forms of Port Campbell australites there are sufficient numbers of specimens to be statistically significant.

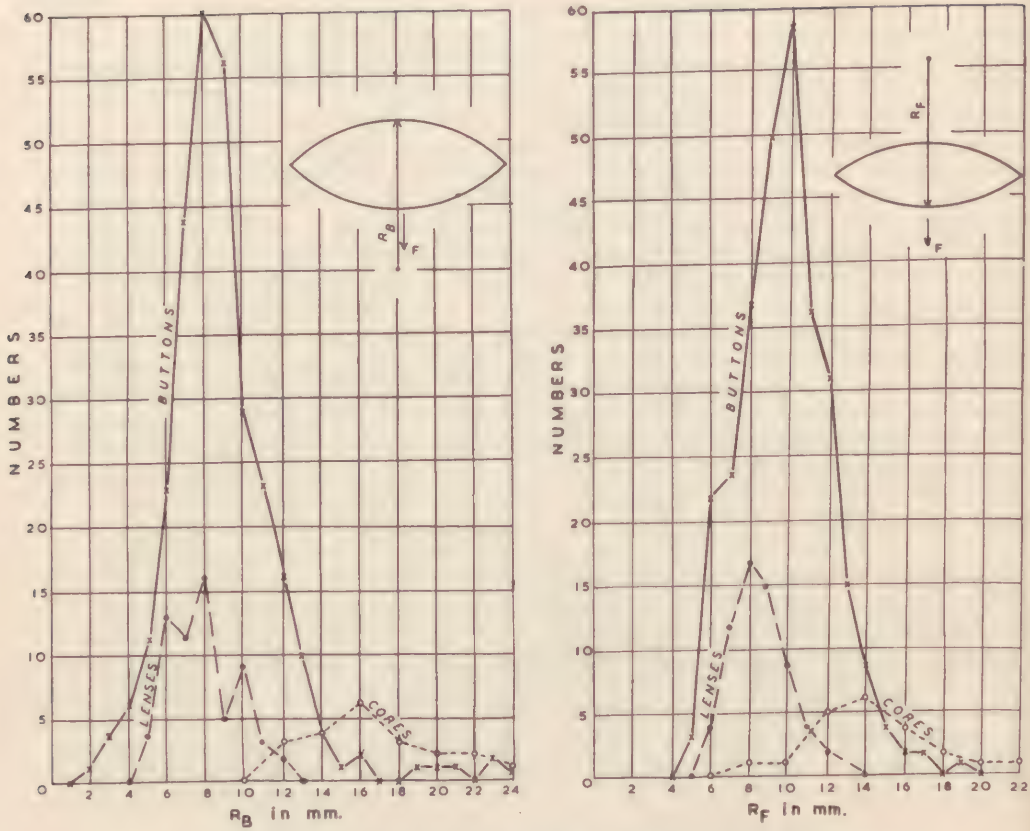
In the scatter diagrams, a particular measurement for each individual form studied in the button, lens and round core types has been plotted against each of the other selected measurements in turn. Because of their closely related values throughout, button-shaped and lens-shaped types have been grouped together for R_B-R_F, for De-Di, for ON-OM, for R_B-De, for R_B-Di, for R_F-De and for R_F-Di comparisons.

In Fig. 4 particular values of R_B, taken to the nearest 1·0 mm., are plotted against numbers of forms possessing the same R_B value for the three main types of the round forms of australites. The greatest numbers of buttons and lenses have an R_B value of 8 mm., while cores have a value double this amount. For R_F values, however, although the values of the mode remain the same for lenses (8 mm.), the value for buttons is increased by 25% to 10 mm., while that for the round cores has decreased 12·5% to 14 mm. (see Fig. 5).

TABLE 4

Modes of Frequency Polygons compared with Calculated Average Values of Curvature and Size Measurements of 385 Round Forms of Port Campbell Australites

Shape Type		R_F (mm.)	R_B (mm.)	Ratio $R_B : R_F$	Diameter (mm.) (Di)	Depth (mm.) (De)	Ratio De : Di	Intercept OM (mm.)	Intercept ON (mm.)	Ratio OM : ON
Buttons ..	Mode of Frequency Polygon	10	8	1 : 1	14	8	1 : 2	3	4	1 : 1·5
	Calculated Average Value ..	9·5	8·5	1 : 1·2	14	7·5	1 : 1·9	3·5	4·5	1 : 1·4
Lenses ..	Mode of Frequency Polygon	8	8	1 : 1	12	6	1 : 2	3	3	1 : 1
	Calculated Average Value ..	8·5	8	1 : 0·9	12	6	1 : 2·1	3	3	1 : 1·2
Round Cores	Mode of Frequency Polygon	14	16	1 : 1	26	14	1 : 2	9	6	1 : 0·5
	Calculated Average Value ..	14	17	1 : 0·9	26	15·5	1 : 1·7	9	6	1 : 0·7



FIGS. 4 and 5.—Frequency polygons showing R_B-Numbers and R_F-Numbers relationships for round forms of the Port Campbell australites.

(The arrow and the letter F in this and other frequency polygons herein indicate the front surface and the direction of propagation of the australites through the earth's atmosphere.)

In Fig. 6, depicting the relationships of the ratio $R_B : R_F$ and the numbers of round forms that possess similar values of this ratio, it is found that by using ratios determined to the nearest 0·5, nearly symmetrical polygons result for all three of the major shape types, each having a modal value at unit ratio. The polygons show (Fig. 6) that the greater numbers of the round forms of australites possess R_F values which are approximately equal to their R_B values, and that there is a significant proportion (37%) in which R_F is 1·5 times as great as R_B.

The relationships between individual R_B and R_F values for the round forms of Port Campbell australites are shown in Fig. 7, which reveals a general tendency for R_F values to increase with increase in R_B values. This is not a steady increase, however, inasmuch as there are, for example, 30 specimens with the same R_F value of 8 mm. and among these specimens there is a range in the R_B values of from 2 to 12 mm. In other words, a number of primary forms with original diameters

ranging from 4 mm. to 24 mm. have all been ablated different amounts to produce ultimate secondary anterior surfaces having the same radius of curvature. These forms, however, do not all have the same depth values nor the same diameter values, hence the arcs of curvature of their posterior and anterior surfaces respectively show different dispositions in relation to their radical lines, so that the centres of the two coaxal circles are variously spaced from the radical lines in the different specimens.

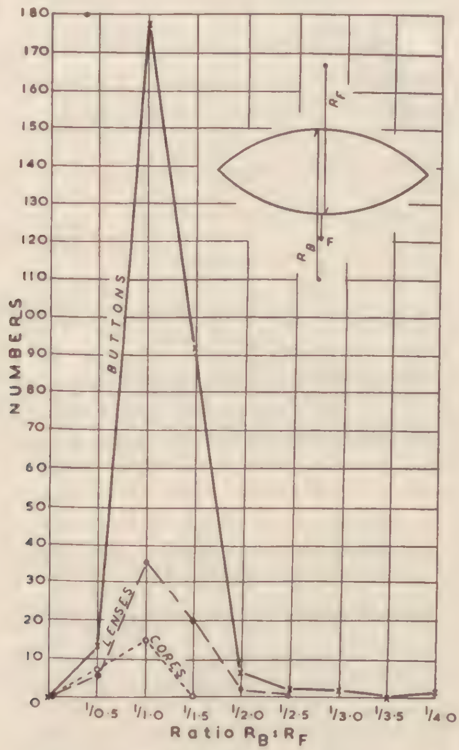


FIG. 6.—Frequency polygon depicting Ratio $R_B : R_F$-Numbers relationships for the round forms of Port Campbell australites.

Conversely, Fig. 7 reveals that there are, for example, about 40 specimens with approximately the same R_B of 8 mm., but these show a range in R_F values of from 5·5 mm. to 12 mm. In other words, 40 of the primary forms possessed a similar diameter of 16 mm., but by differential ablation, their ultimate secondarily formed anterior surfaces have different arcs and different radii of curvature, and hence different depths and different diameters.

Similar such variations as those outlined above occur for other values of both R_F and R_B. Despite these variations, the total scatter for all the round forms included in the comparisons nevertheless reveal the general trend of increasing R_F with increase in R_B; that is to say that with flatter arcs of curvature of posterior surfaces, which are usually encountered on the larger primary forms, the flatter arcs of curvature of secondarily produced anterior surfaces develop.

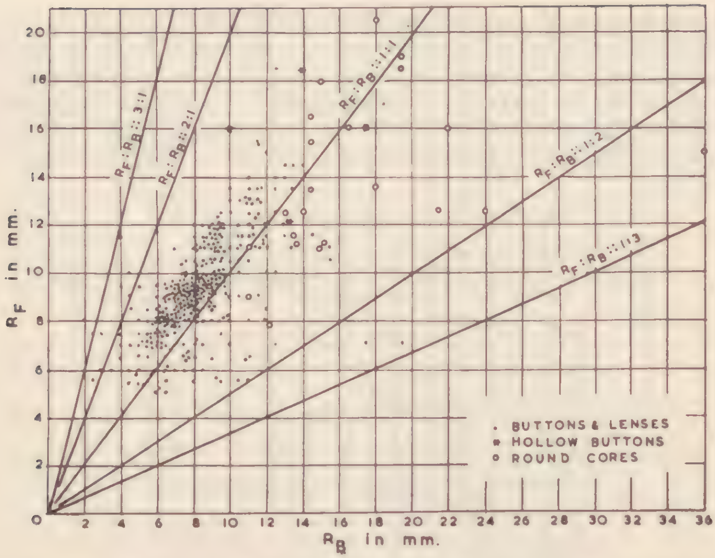


FIG. 7.—Scatter diagram illustrating R_F-R_B relationships for each individual round form of the Port Campbell australites. (Round discs and round bowls excluded because of low numbers in each shape type, anomalous curvatures in round bowls and usually flat surfaces in round discs.)

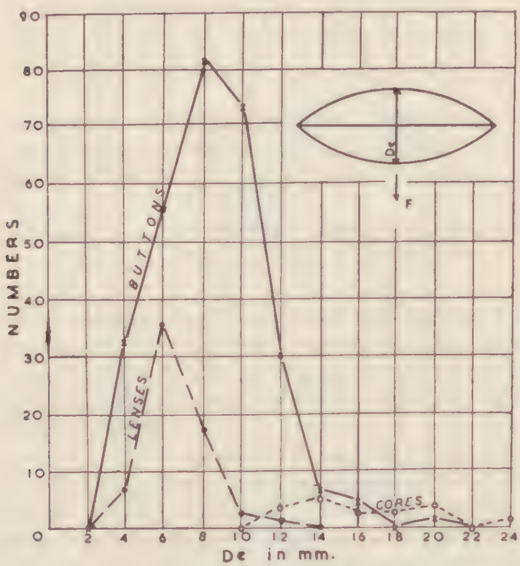


FIG. 8.—Frequency polygon showing Depth-Numbers relationships for round forms of the Port Campbell australites.

Fig. 7 shows a marked concentration of R_F-R_B values for buttons and lenses between the unit gradient line and the 2 : 1 gradient line. R_F-R_B values for the round cores show a considerable scatter.

The depth values of the round forms of australites from the Port Campbell district are shown in Fig. 8, where it can be observed that lenses, with depth values of 6 mm., are not as thick as buttons, in which the modal value is 8 mm., although significant numbers have depth values of 10 mm. The round cores are even thicker, but the distribution of their depth values is somewhat irregular, possibly partly because of lower numbers of specimens.

The distribution of diameter (Di) values (Fig. 9) follows similar trends as for the depth values, inasmuch as lenses possess the lesser diameters with the mode at 12 mm., but significant numbers of specimens of lenses have a diameter of 10 mm. Buttons reveal a marked mode at 14 mm., with significant numbers of specimens having diameters of 10 mm., 12 mm. and of 16 mm. on either side of the mode of the polygon. Round cores again show higher values still, but again also a widespread distribution of those values.

Plotting the ratios of depth to diameter, based upon numbers of specimens possessing similar ratios of De to Di (Fig. 10), reveals that the ratio for both buttons and lenses is characteristically 1 : 2, but significant numbers of the button-shaped australites have a ratio of 1·0 : 1·5. The round cores show a similar 1 : 2 trend, but this is by no means as marked as in the button- and lens-shaped types where there are much larger populations.

The scatter diagram depicting depth and diameter values for individual specimens of the round forms of australites from Port Campbell typically reveals a general and steady increase of diameter values with increase in depth values (Fig. 11). Most of the values are concentrated in the region of the 1 : 2 gradient line. Here again, as noted also for Fig. 7, there is observed a number of examples having the same depth value but a range in diameter values, and vice versa, but this does not radically affect the general trend of increasing diameter with increasing depth. Specimens with the same depth but different diameters reflect an origin from primary forms of originally different diameters, ablated to different degrees to yield ultimate secondary shapes of similar depth. Specimens with the same diameters but different depths point to an origin from primary forms of similar original size, ablated to different degrees to yield ultimate secondary shapes of different depth.

Such variations in the ablation process during earthward atmospheric flight seem to indicate somewhat varying speeds of transit and/or possibly different lines of flight through the earth's atmosphere. Faster-moving specimens, although taking slightly less time to traverse the thickness of the earth's atmosphere, may have suffered deeper ablation effects. Somewhat slower-moving specimens may have had longer lines of flight through the atmosphere, and hence suffered comparable degrees of ablation. Slower-moving specimens traversing shorter earthward paths would be probably less ablated than faster-moving specimens traversing similar shorter earthward paths.

The relationships of the intercepts OM and ON cut off by the intersection of the radical line on the depth line (*cf.* Fig. 3) for the round forms of the Port Campbell australites are shown in Figs. 12 to 15. Most of the OM values for buttons and lenses fall on the 3 mm. co-ordinate (Fig. 12), with significant numbers having a value of 4 mm., while most of the ON values for buttons (Fig. 13) fall in the 3 mm. to 6 mm. range, those for lenses occurring at a prominent mode of

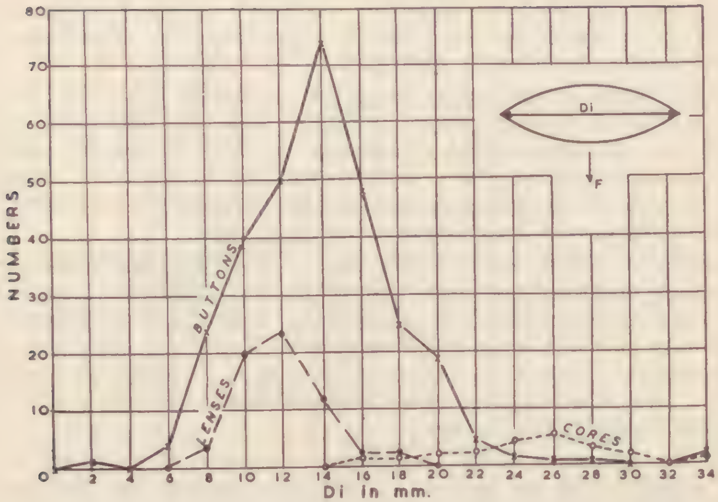


FIG. 9.—Frequency polygon showing Diameter-Numbers relationships for round forms of the Port Campbell australites.

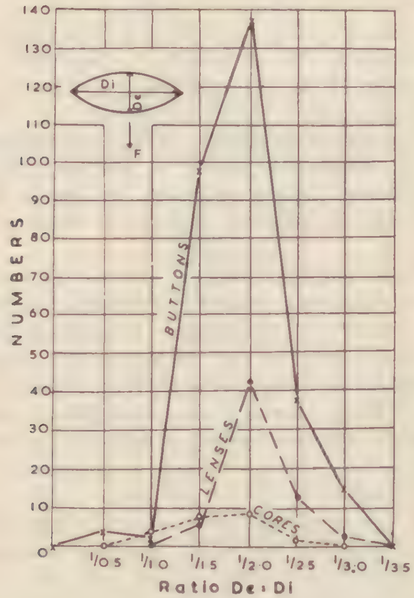


FIG. 10.—Frequency polygon showing De : Di - Numbers relationships for round forms of the Port Campbell australites.

3 mm. Round cores show a tendency towards modes of 9 mm. for OM values (Fig. 12) and of 6 mm. for ON values (Fig. 13).

Relationships between the ratio OM : ON and numbers possessing the same ratio value among the round forms of the Port Campbell australites are shown in Fig. 14. Here the button-shaped forms provide a mode at the 1 : 1·5 ratio, but almost similar numbers yield a 1 : 1 ratio, thus indicating that the button-shaped australites are largely lenticular in cross sectional aspect, but by no means all have the perfect symmetry indicated in cross sectional aspect by the lens-shaped types,

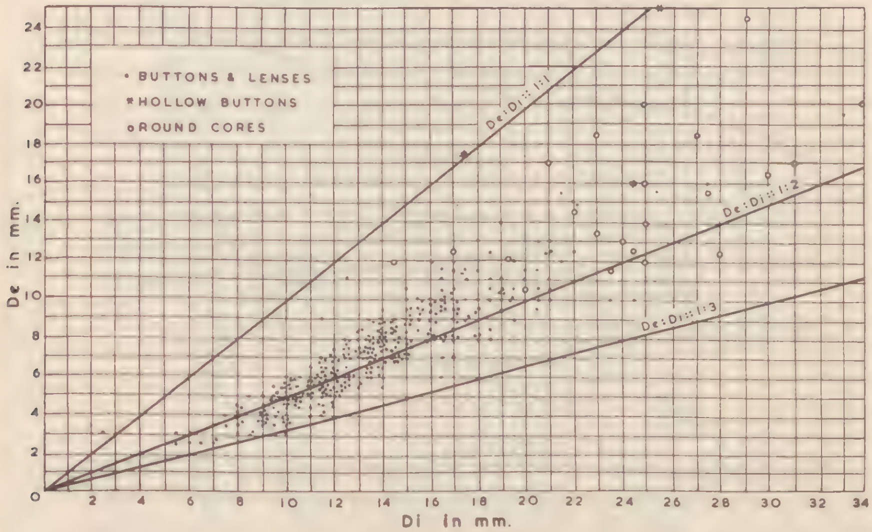
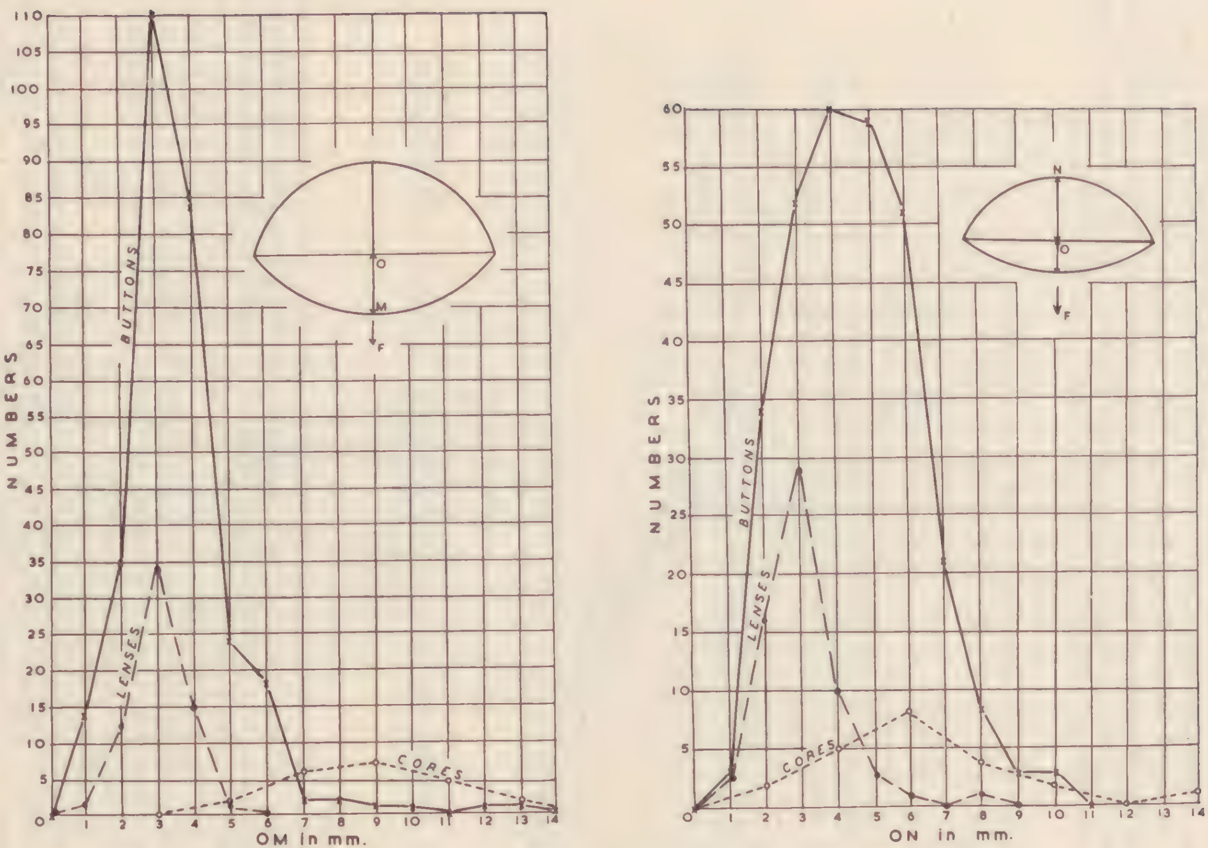


Fig. 11.—Scatter diagram showing Depth (De)-Diameter (Di) relationships for each individual round form of the Port Campbell australites. (Round discs and round bowls excluded.)

which provide a prominent mode at unit ratio. In these forms with a 1 : 1 ratio it is evident that the front and back poles are equally spaced from the mid-point of the specimen, and the plane containing the mid-point (i.e. the horizontal plane containing K, O and L in Fig. 3) is thus virtually a plane of symmetry. In round cores, on the other hand, most examples have OM : ON ratios of 1 : 0·5, which means that in the majority of such specimens the back pole is spaced closer to the horizontal plane than is the front pole, and hence the horizontal plane containing K, O and L is not a plane of symmetry.

Fig. 15, illustrating the relationships between values of OM and ON for individual round forms of australites from Port Campbell indicates that there is a general, even if somewhat scattered and rather irregular, increase in OM values with increase in ON values. The greatest number of OM and ON values for buttons and lenses fall between the 1 : 1 and the 2 : 1 gradients of ON : OM in Fig. 15, but the values for round cores are widespread and range from 1·5 : 1 to the 1 : 4·5 gradients.



FIGS. 12 and 13.—Frequency polygons showing OM-Numbers and ON-Numbers relationships for round forms of the Port Campbell australites.

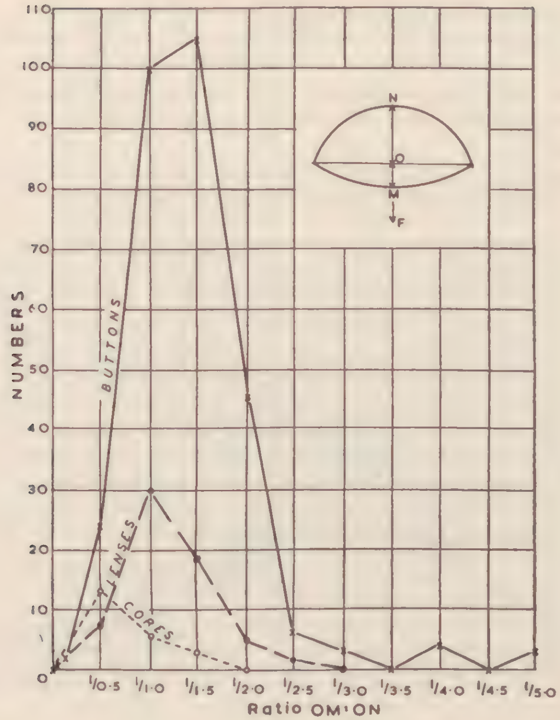


FIG. 14.—Frequency polygons showing OM : ON - Numbers relationships for round forms of the Port Campbell australites.

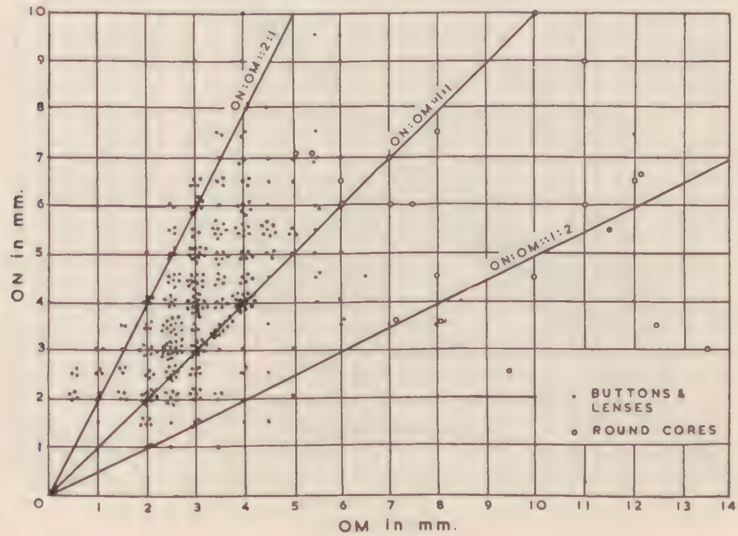
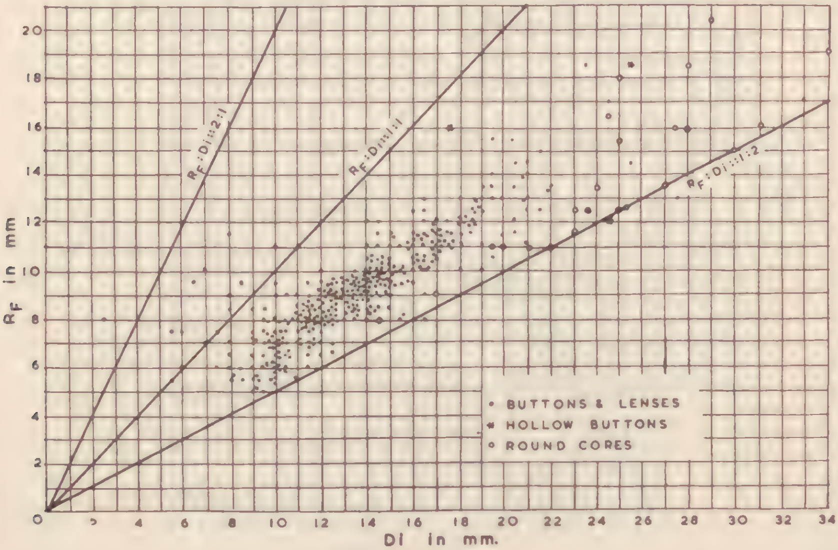
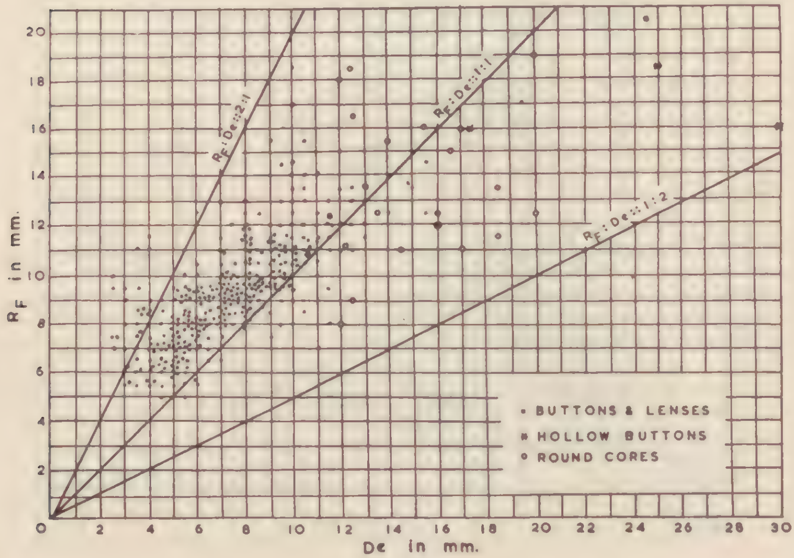


FIG. 15.—Scatter diagram showing ON-OM relationships for each individual round form of the Port Campbell australites.

Scatter diagrams for the relationships between each of the following pairs of values, viz., R_F - ON, R_B - ON, R_F - OM, R_B - OM, Di - ON, Di - OM, De : Di - OM : ON, $R_B : R_F$ - De : Di, $R_B : R_F$ - OM : ON, R_F - Di, R_B - Di, R_F - De and R_B - De, all show interesting and somewhat comparable trends, but of these, only R_F - Di, R_F - De, R_B - Di and R_B - De are reproduced herein (Figs. 16 to 19).

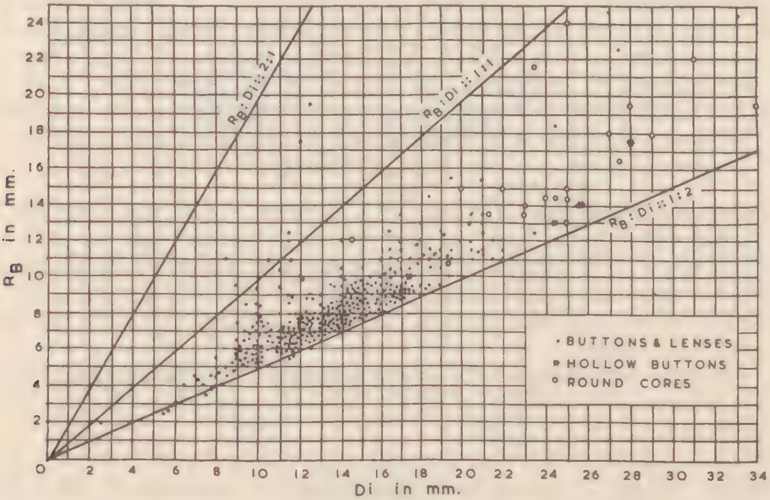


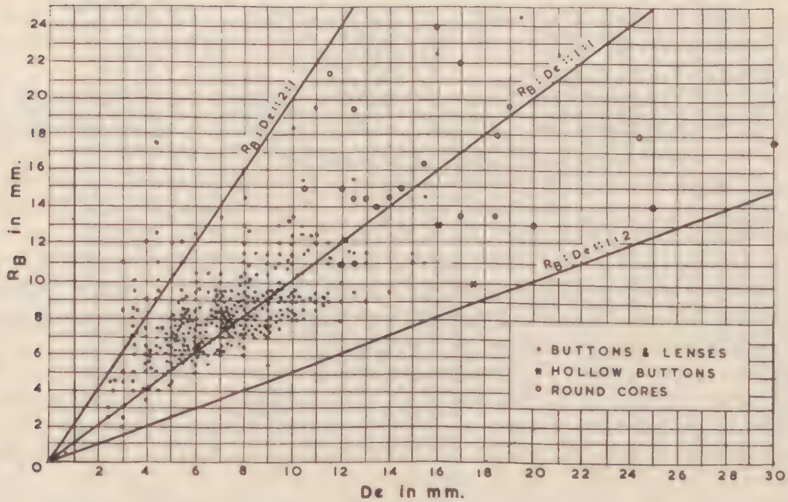


FIGS. 16 and 17.—Scatter diagrams showing R_F-Di and R_F-De relationships for individual round forms of the Port Campbell australites.

R_F - Di and R_F - De relationships (Figs. 16 and 17) reveal that the values for R_F are preponderantly less than Di values, but dominantly greater than De values. The general tendency in each comparison is for R_F to increase in value with increases in both Di and De.

In comparisons of the radius of curvature (R_B) of the preserved remnant portion of the primary posterior surface (Figs. 18 and 19), it is found that values for R_B are just as preponderantly less than Di values as are the R_F values, but that fewer R_B values are greater than depth values (Fig. 19) compared to the R_F values





FIGS. 18 and 19.—Scatter diagrams showing R_B-Di and R_B-De relationships for individual round forms of the Port Campbell australites.

that are greater than depth values (Fig. 17). In all of the scatter diagrams depicted in Figs. 16 to 19 there is a notable increase in both depth and diameter values with increase in both R_F and R_B values, this trend being best marked in R_F - Di and in R_B - Di relationships.

Relationships of Series of Forms having one Common Factor

Although the scatter diagrams reveal generally increasing values for one particular factor as values increase for any other selected factor utilized in the above comparisons, there are, nevertheless, certain numbers of specimens which have the same value for one given factor, but the other factors with which this is compared may show quite a considerable range in values. Thus, basing the comparisons fundamentally upon R_B relationships in the first place, since the back surface is more significant in being a representative remnant of the original primary form, it is found that the following trends result from examining a series of randomly selected values:

(i) there can be various Di values for a number of forms possessing the same R_B values;
(ii) there can be various De values for a number of forms possessing the same R_B values;
(iii) there can be various values of R_B for a number of forms possessing the same Di values;
(iv) there can be various R_B values for a number of forms possessing the same De values.

Treatment 1

In Table 5, where 74 round form specimens are represented, each having the same value (8 mm.) for R_B, there is revealed increasing depth as the diameter increases from 9 to 16 mm. In a similar way, it has been found that for a series of 24 round form specimens possessing the same value (10 mm.) for R_F, as the diameter varies from 12 to 19 mm., the depth values for these specimens show an increase from 5·5 to 11 mm.

For such an increase in depth with increase in diameter of forms having the same R_B there must also be equivalent variations in the values of R_F, and the centres of the coaxal circles circumscribed about the posterior and anterior surfaces respectively must lie at different, but not necessarily progressive, positions on the ON intercept (or its continuation) of Fig. 3. The relationships of these factors for round forms having the same R_B of 8 mm. are shown in Fig. 20.

It can be seen from Fig. 20 that as diameter increases there is a generally regular increase in depth and likewise an increase in R_F. Table 5 shows the respective R_F values obtained by construction from the known values of depth and diameter variations for a constant R_B.

Averages of the actual R_F measurements in each of the groups *a* to *h* agree generally with the values of R_F for each group determined by the constructions depicted in Fig. 20. Projection on to a common diameter line of the various diameters shown in Fig. 20 yields the relationships of cross sections illustrated in Fig. 21.

Such a series of progressively smaller end shapes as those depicted in Figs. 20 and 21 point to an origin from the regular differential ablation of original glassy spheres of similar size. As ablation processes rapidly proceed during high-speed

earthward flight, there is a progressive diminution in depth and diameter with loss of melted glass from the forwardly directed surface. At the same time, there is a tendency for the radius of curvature of the secondarily produced anterior surface (i.e. R_F) to increase at first, so that earlier formed arcs of curvature are flatter. After passing the equatorial periphery of the original sphere, R_F values mostly tend to decrease until in the smaller forms so produced R_F becomes less than R_B. Hence R_F also becomes less than the radius of the original sphere, and so the front surface finally develops a steeper arc of curvature than that of the remnant

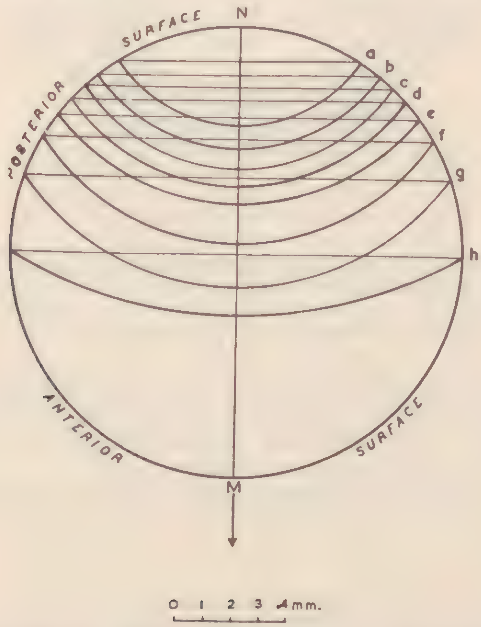


FIG. 20.—Relationships of diameter, depth and R_F for a series of round forms of the Port Campbell australites having the same R_B of 8 mm. (Arrow below M represents direction of propagation through the earth's atmosphere. N = back pole, M = front pole.)

TABLE 5

R_B (mm.)	Di (mm.) (average of measurements)	De (mm.) (calculated average)	R_F (mm.) (by construction)	Cross Section on Figs. 20 and 21	Percentage of group in the series
8	9	3·5	5·8	a	1·5
8	10	4·3	6·4	b	6·5
8	11	5·0	8·0	c	4·0
8	12	5·6	8·4	d	12·5
8	13	6·2	9·2	e	12·5
8	14	7·7	9·5	f	44·0
8	15	9·2	9·6	g	12·5
8	16	10·2	15·1	h	6·5

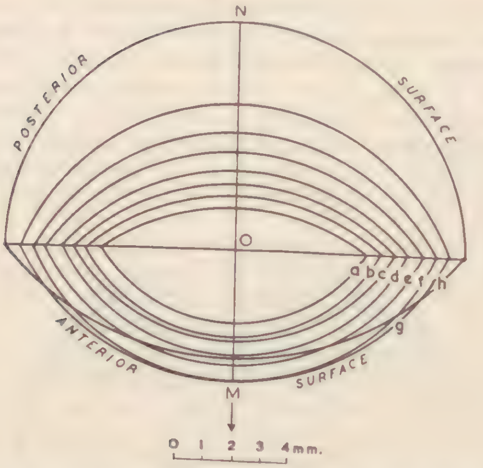


FIG. 21.—Relationship of cross sectional shapes obtained by projecting the diameters of Fig. 20 on to a common diameter line. (Arrow beneath M indicates direction of earthward trajectory. N = back pole, O = centre of circular horizontal plane containing the diameter line, M = front pole.)

primary posterior surface. For this end to be achieved there must have been increased equatorial ablation and fusion-stripping among the smaller forms. On the other hand, in the earlier stages of the development of a secondary anterior surface, polar ablation must have been dominant.

Similar results to those outlined above have been achieved by utilizing other R_B values than the 8 mm. value employed in Table 5 and in Figs. 20 and 21.

Treatment 2

Treatment 2 is the corollary of Treatment 1, and similar results are obtained by considering a series of 70 specimens each having the same R_B of 8 mm., but with depth varying from 4 to 12 mm. By calculation of the average diameters for each group, it is found that diameter values progressively increase in the manner shown by Table 6. Comparable trends also result by selecting groups of specimens with the same R_F value. The relationships for the round forms having the same R_B of 8 mm. are shown in Fig. 22.

TABLE 6

R_B (mm.)	De (mm.) (average of measurements)	Di (mm.) (calculated average)	R_F (mm.) (by construction)	Cross Section on Fig. 22	Percentage of group in the series
8	4	9·7	6·3	a	4
8	5	10·7	6·4	b	11
8	6	12·2	7·5	c	16
8	7	13·3	8·3	d	15
8	8	13·7	8·0	e	24
8	9	14·3	7·6	f	16
8	10	15·2	8·7	g	11
8	11	15·5	8·5	h	1·5
8	12	16·0	10·0	i	1·5

Fig. 22 reveals a similar trend to that of Fig. 20. As depth decreases, there is a proportional decrease in diameter and at the same time a general decrease in the R_F values, as shown in Table 6.

Averages of the actual measurements of R_F in each of the groups *a* to *i* show fair agreement with the values of R_F (see Table 6) determined by construction from Fig. 22. The origin of these series of secondary end shapes can be explained in terms identical with those already set out in Treatment 1.

Similar trends are again revealed by selecting R_B values other than 8 mm. for identical treatment.

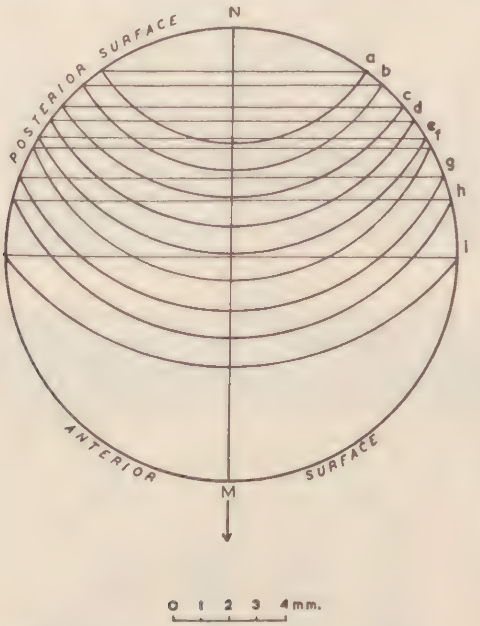


FIG. 22.—Relationship of depth, diameter and R_F for a series of round forms of the Port Campbell australites having the same R_B of 8 mm. (Arrow below M indicates direction of earthward trajectory. N = back pole, M = front pole.)

It is noted from the constructions shown in Figs. 20 to 22 that in each group of specimens the diameter lines are largely situated closer to the back than to the front pole, so that the intercept ON is usually less than the intercept OM for smaller forms, but vice versa for larger forms. The values for the intercepts ON and OM, and the ratio OM : ON for the two series of forms dealt with in Treatment 1 and Treatment 2, are shown in Table 7.

Both series of specimens listed in Table 7 show similar trends, in that for each the ratio OM : ON varies from in the region of 1 : 0·6 in the secondary shapes of smaller size, to approximately unit ratio for secondary shapes of intermediate size. In the larger specimens, ON has increased to such an extent that the value for this intercept is over twice that of the OM intercept, so that the front pole (M) is thus much closer to the mid-point of the horizontal plane that contains the diameter line (*cf*. group h, Fig. 21).

TABLE 7

Showing Intercept Values of the two Series of Forms dealt with in Treatment 1 and in Treatment 2.

Group	Treatment 1 (cf. Fig. 20)				Treatment 2 (cf. Fig. 22)			
	Percent	ON (mm.)	OM (mm.)	Ratio OM : ON	Percent	ON (mm.)	OM (mm.)	Ratio OM : ON
a	1·5	1·2	2·3	1 : 0·52	4	1·5	2·5	1 : 0·60
b	6·5	1·7	2·6	1 : 0·65	11	2·0	3·0	1 : 0·66
c	4·0	2·1	2·9	1 : 0·72	16	2·8	3·2	1 : 0·88
d	12·5	2·6	3·0	1 : 0·87	15	3·3	3·7	1 : 0·90
e	12·5	3·1	3·0	1 : 1·03	24	3·9	4·1	1 : 0·95
f	44·0	3·9	3·7	1 : 1·06	16	4·3	4·6	1 : 0·94
g	12·5	5·3	3·9	1 : 1·36	11	5·3	4·7	1 : 1·12
h	6·5	8·0	2·1	1 : 3·81	1·5	6·1	4·8	1 : 1·27
i	—	—	—	—	1·5	8·0	3·9	1 : 2·05

Treatment 3

The relationships of 30 specimens having the same diameter value of 10 mm., but with R_B varying from 5 to 10 mm., show a steady decrease in depth values as the R_B values increase in amount. At the same time R_F values show a decrease followed by an increase. These variations are listed in Table 8. The relationships

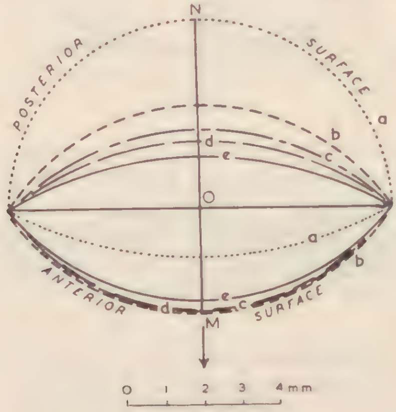


FIG. 23.—Relationships of R_B, depth and R_F for a series of round forms of Port Campbell australites having the same diameter value of 10 mm. (Arrow below M represents direction of flight through the earth's atmosphere. N = back pole, O = mid-point of diameter line, M = front pole.)

of these factors are diagrammatically illustrated in Fig. 23. Similarly designated curves on either side of the diameter line in Fig. 23 appertain to the cross-sectional outline of one and the same form group. In this series of forms with the same diameter value it is observed from Fig. 23 that most of the groups (e.g. b, c, d and e) have closely similar radii and arcs of curvature of the secondarily pro-

duced front surfaces, but marked differences for the corresponding back surfaces. Variations in depth cannot be clearly detected from Fig. 23 but are listed in Table 8.

TABLE 8

Di (mm.)	R_B (mm.) (average of measurements)	De (mm.) (calculated average)	R_F (mm.) (by construction)	Cross Section on Fig. 23	Percentage of group in the series
10	5	5·5	10·5	a	10
10	6	5·2	6·0	b	40
10	7	4·8	5·9	c	25
10	8	4·5	5·8	d	18
no sp.	9	—	—	—	—
10	10	3·7	6·4	e	7

Examination of 44 specimens having the same diameter of 12 mm. reveals similar trends to those outlined for the series of specimens having a constant diameter of 10 mm. The trend for R_B increases and depth variations are shown by the values listed in Table 9.

TABLE 9

Di (mm.)	R_B (mm.) (average of measurements)	De (mm.) (calculated average)	Percentage of group in the series
12	6	7·1	16
12	7	6·2	41
12	8	5·6	20
12	9	4·7	7
12	10	4·5	5
12	11	5·5	2
12	12	4·5	5
12	13	4·5	2
12	18	4·5	2

Somewhat comparable relationships are obtained for a series of 20 forms having the same diameter and with R_F values increasing from 5·5 to 8·0 mm. Such a group reveals a decrease of depth from 5·5 to 4·3 mm., but variations in R_B are somewhat irregular in this series.

The secondary shapes examined in Treatment 3 indicate that end forms with the same ultimate diameter may be derived from original spheres ranging in size from 10 to 22 mm. across. This points to different degrees of ablation. During the process there results the following forms among the secondary shapes of australites:

(a) Bilaterally symmetrical, lenticular shapes (in radial section aspect) with similar arcs of curvature for secondarily developed anterior and remnant primary posterior surfaces, such forms possessing an equivalent distribution of glass on either side of the plane containing the radical (= diameter) line.

(b) Forms with R_F markedly greater than R_B and with a greater proportion of australite glass on the back pole side of the plane containing the radical line.

(c) Forms with R_B distinctly greater than R_F and hence a much flatter arc of curvature of the posterior surface, and a greater proportion of australite glass on the front pole side of the plane containing the radical line.

(d) Forms intermediate to those of (a) and (c).

A series such as this indicates that with differential ablation, whereby originally larger primary spheres (or spheroids approximating spheres) have been reduced to secondary end shapes of the same diameter and generally similar size, there has nevertheless been maintenance of stability of position during flight. This is deduced from the fact that each group of the series possesses arcs of curvature suited to constructed coaxal circles, with the centres of the circles being located on the depth line NM or its extension beyond the limits of the forms, and hence collinear.

Treatment 4

If a series of 50 forms having the same depth value of 8 mm. is studied, it is found that diameter values increase fairly regularly from 11·5 to 19·5 mm. with increase of R_B values (see Table 10). At the same time, both R_B and R_F values increase regularly, and since the R_B and R_F values are virtually the same as one another in each group of the series, almost perfect lenticular shapes result in radial section aspect, as depicted in Fig. 24.

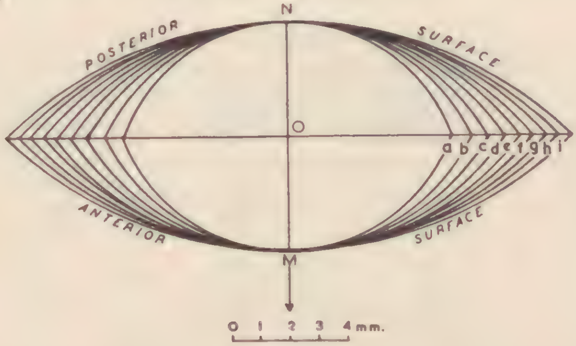


FIG. 24.—Relationships of R_B, diameter and R_F for a series of round forms of Port Campbell australites having the same depth value of 8 mm. (Arrow below M represents direction of propagation through the earth's atmosphere. N = back pole, O = mid-point of diameter line, M = front pole.)

It can be seen from Fig. 24 that with constant depth for this series of specimens, as diameter increases, both R_B and R_F increase similar amounts, hence both arcs of curvature become flatter in the larger of the secondary shapes. The values showing these increasing trends are listed in Table 10.

A series of forms thus result having (*cf.* Fig. 24) bilateral symmetry as well as radial symmetry. Each group therefore possesses almost perfect lenticular secondary shapes. The diameter, R_B and R_F values regularly increase from group to group in the series. The deduction is that there has been a progressive reduction in size by the ablation of spheres of an original size range of 12 to 28 mm. across. The originally larger spheres, however, have necessarily been subjected to greater amounts of equatorial fusion-stripping and ablation than the originally smaller spheres.

TABLE 10

De (mm.)	R_B (mm.) (average of measurements)	R_F (mm.) (by construction)	Di (mm.) (calculated average)	Cross Section on Fig. 24	Percentage of group in the series
8	6	6	11·5	a	2·0
8	7	7	12·5	b	22·5
8	8	8	14·0	c	32·5
8	9	9	15·0	d	16·5
8	10	10	16·0	e	12·0
8	11	11	17·0	f	6·0
8	12	12	18·0	g	2·0
8	13	13	18·5	h	4·5
8	14	14	19·5	i	2·0

Production of Secondary Button Shape from Primary Sphere

The above illustrations indicate that the secondary button shapes, which are among the most commonly developed types of australites, were evidently derived from either primary spheres or possibly from spheroids little removed from true spheres in shape.

It is believed (Baker, 1955) that all australites are secondary shapes, produced from a few primary glassy forms by a process of ablation-reduction assisted by fusion-stripping, during passage through the earth's atmosphere at ultra-supersonic velocities of originally cold, non-rotating bodies composed of more or less homogeneous material. The development of shock waves in the air ahead of such rapidly moving objects caused temperature and pressure rises requisite for superficial sheet fusion and the operation of drag effects by skin friction. These two processes were most important in sculpturing the forwardly-directed surfaces of the primary forms, and in producing the ultimate secondary shapes possessed by australites as found. Some of the fused glass was lost by ablation or evaporation, some was whipped away at high speed flight by straight-out fusion-stripping effects without necessarily passing into the vapour state. An original sphere and typical secondary, ultimate button shape produced therefrom are depicted in sectional aspect in Fig. 25.

In Fig. 25 the arrow indicates the direction of propagation at ultra-supersonic speeds through the earth's atmosphere. N represents the position of the back pole on the posterior surface, M the front pole on the anterior surface, and O the point of intersection of the depth line (NM) and the diameter line of the secondarily produced button-shaped form. The circle (broken line) constructed about the arc of curvature of the secondarily developed front (anterior) surface coincides with this front surface in the polar regions, and just meets the crests of the inner flow ridges (i.e. the ridges nearer to the polar regions). Towards the equatorial regions of the front surface, however, the arc of curvature of the flange becomes steeper. In many examples this curvature is flatter, and in a few flanged forms the arc of curvature remains concordant with that of a constructed circle, and hence contiguous with the arc of curvature of the anterior surface of the body of the form. The arc of curvature of the remaining portion of the bubble-pitted posterior surface, indicated by a serrated line in Fig. 25, is part of the arc of curvature of a constructed circle corresponding to a section through a sphere. The posterior surface, which is the top surface in Fig. 25, is regarded as an unaltered residual portion of the original primary form (sphere), and hence its radius of curvature provides the original diameter of the primary form.

The flow ridges depicted in sectional aspect in Fig. 25, and also in the sketch of the normal flanged button in Fig. 1, are separated by "flow troughs". The circles constructed about the arcs of curvature of anterior surfaces carrying such flow ridges often fit across the tops of these flow ridges, more particularly the ones situated nearest the front polar regions. Added to the observations (Baker, 1955) made on the internal flow patterns in the regions where flow ridges and "flow

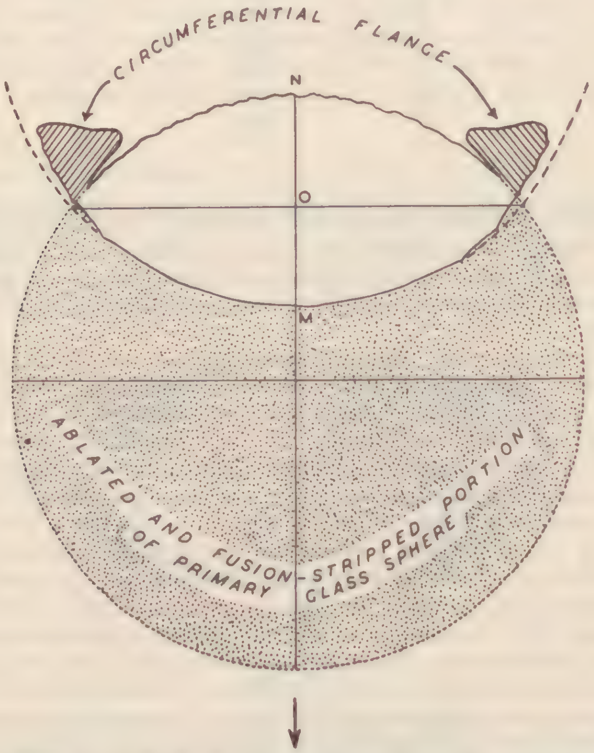


Fig. 25.—Illustrating ablation-reduced and fusion-stripped original sphere of australite glass from which was produced a secondary button-shaped Port Campbell australite having the following dimensions:

R_F = 14·5 mm.	R_B = 13·5 mm.
De = 10·0 mm.	Di = 21·0 mm. (ex-flange)
OM = 4·5 mm.	ON = 5·5 mm.

troughs" occur, the geometrical position of the ridges indicates that some glass has been removed from the "flow trough" regions, more especially towards the equatorial periphery of each form. The term "flow trough" is thus descriptive of appearance and does not embody an indication of origin. Rather than "waves" of superficially molten glass being generated during movement under pressure and drag from front polar to equatorial regions, it is evident that softened glass has been removed by fusion-stripping from the "flow trough" regions, leaving the slightly projecting ridge-like structures. This applies more particularly to the final stages in the secondary sculpturing processes producing the front surfaces of australites.

Fig. 25 indicates that a considerable proportion of the glass of the original sphere has been lost by ablation and fusion-stripping processes. A small proportion of secondarily melted glass has been accumulated around the periphery of the equatorial regions of the posterior surface, by a process of drag, resulting in the growth of a circumferential flange. Although produced rapidly, as an outcome of the high speed of transit of the object through the earth's atmosphere, it is considered likely that at any particular instant the amount of sheet fusion was never great, and did not exceed 0·01 mm. in thickness before removal occurred under the influence of skin friction and the like. The object was thus not heated throughout, rear portions remaining at low temperatures and low pressures, as testified to by the fact that the rate of heat transference through australite glass is very low (*cf.* Baker, 1955) and by the fact that there would be generated a region of dead air behind the object moving through a not highly-resistant medium at ultra-supersonic velocity.

There are other examples of button-shaped australites in which the end product indicates that rather less material was ablated and fusion-stripped from the original primary sphere of glass, and some in which rather more material was removed. On the whole, however, the original form was reduced by at least one-half to two-thirds of its bulk before conditions were favourable for the production and preservation in place of the circumferential flange. Subsequent removal of the flange under the effects of increased equatorial fusion-stripping during the near-final stages of atmospheric flight resulted in the production of the non-flanged, lens-shaped types of australites which possess a much smaller number of flow ridges on their forwardly directed surfaces.

Summarized Curvature-Size Relationships

The various factors concerned with curvature and size which have been determined for the well-preserved round forms of australites discovered in the Port Campbell district are compared on a percentage basis in Table 11.

It is seen from Table 11 that for almost three-quarters of the specimens the radius of curvature of the front surface (R_F) is in excess of that of the back surface (R_B), so that many of the forms have rather flatter anterior than posterior surfaces. Few are equal in value, resulting in the same arc of curvature for each surface. Approximately one-fifth possess flatter back surfaces (i.e. $R_B > R_F$), and most of the round cores belong to this category. Comparable relationships have been found for the Nirranda district australites (Baker, 1955).

In diameter-depth relationships, the diameter is almost universally greater than the depth, as for the Nirranda australites. As shown by the frequency polygon (Fig. 10) and scatter diagram (Fig. 11), diameter values are typically approximately twice the depth values.

In the relationships of both the depth and the diameter values to the radii of curvature values for anterior (R_F) and posterior (R_B) surfaces respectively, it is found that diameter is greater than both R_F and R_B for the majority of specimens, more so with R_B than with R_F. Specimens with R_F greater than or equal to their respective diameter values consist largely of the very small buttons and the small round discs and round plates. Specimens having R_B equal to or greater than their respective diameter values are very rare among the button-shaped australites, and only one or two occur among the lenses. Depth values are principally less than both R_F and R_B values, but the hollow buttons and most of the round cores have depth values somewhat in excess of R_F values (*cf.* Fig. 17). Several of the

TABLE 11

Percent Relationships of R_F, R_B, Di, De, OM and ON for 405 Round Forms of Port Campbell Australites.

Factors Compared	Relationship of Factors	Percentage
$R_F - R_B$	$R_F > R_B$ $R_F = R_B$ $R_F < R_B$	70·0 8·0 22·0
Di − De	Di > De Di = De Di < De	99·25 0·25 0·50
R_F − Di	R_F > Di R_F = Di R_F < Di	4·2 1·5 94·3
R_B − Di	R_B > Di R_B = Di R_B < Di	1·8 0·5 97·7
R_F − De	R_F > De R_F = De R_F < De	84·0 4·5 11·5
R_B − De	R_B > De R_B = De R_B < De	61·5 10·5 28·0
OM − ON	OM > ON OM = ON OM < ON	19·5 16·0 64·5
R_F − OM	R_F > OM R_F = OM R_F < OM	98·2 0·5 1·3
R_F − ON	R_F > ON R_F = ON R_F < ON	100·0 0·0 0·0
R_B − OM	R_B > OM R_B = OM R_B < OM	100·0 0·0 0·0
R_B − ON	R_B > ON R_B = ON R_B < ON	98·0 0·5 1·5

normal size buttons, a few of the lenses and round cores, and one hollow button possess depth values which are greater than R_B values (*cf.* Fig. 19).

Among the relationships between the intercepts OM and ON cut off the depth line by the intersecting radical line (= diameter line), it is found that in approximately two-thirds of the specimens ON exceeds OM, although in many such specimens this excess is small, the difference being up to and little more than 0·5 mm. Specimens with OM in excess of ON are found to be mostly round cores and some buttons.

R_F is invariably greater in value than ON, and R_B invariably greater than OM. In few examples, OM is equal to or greater than R_F, as in one hollow button and two round cores. ON is equal to or greater than R_B in two other hollow buttons and one normal button.

Conclusions

A study of the curvature-size relationships of the round forms of australites from the Port Campbell district in Victoria stresses the marked symmetrical character of the secondary end shapes that have resulted from original spheres by the regular ablation and fusion-stripping at high speeds of propagation through the earth's atmosphere. This almost perfect symmetry shown by virtually all the forms that have not been modified by terrestrial weathering is seldom encountered among the components of the tektite strewnfields in other parts of the world.

The relationships of the arcs of curvature and the radii of curvature of the posterior and anterior surfaces, and the general dependance of the diameter, depth and intercept (OM and ON) values upon variations in radii of curvature, indicate the maintenance of steady lines and positions of flight through the atmosphere. This deduction is supported by the fact that the curvatures of the two surfaces of any one secondary shape are coincident with the arcs of curvature of two coaxal circles, added to which it is found that the foci of such circles are collinear, both lying on the polar axis, which in each form was maintained in line with the direction of propagation through the earth's atmosphere. Although the curvature-size relationships do not, in themselves, rule out the suggestion of the possibility of rotatory motion about the polar axis, other evidence has been accrued (Baker, 1955) which indicates that no rotation occurred during the phase of atmospheric flight, so that the secondary end shapes are not products of rotary motion. Apart from the primary spheres, however, all other primary forms were themselves initially forms of revolution, but were evidently developed as such in an extra-terrestrial environment. The development of the secondary end shapes discussed herein is regarded as being consequent upon a secondary phase of superficial front surface heating of the primary glass bodies, which entered the earth's atmosphere as cold objects, at ultra-supersonic speeds (Baker, 1955). Frictional drag and pressure effects in the boundary layers and shocks waves generated at such high velocities of earthward trajectory were responsible for shaping the anterior surfaces and so developing the secondary australite shapes such as are found upon the earth's surface.

Part II—Elongated Forms

Introduction

The term "elongated" australites is restricted to forms having one diameter greater than the other, so that such forms have width and length in contrast to the constant diameter of the round forms of australites. Based on Fenner's (1940) classification of australite shapes, the elongated australites include ovals, boats, canoes, dumb-bells, teardrops and elongated cores.

The complete or nearly complete elongated forms of the Port Campbell australites, which are sufficiently well preserved for accurate curvature and size measurements, comprise 166 specimens distributed among the various shape types according to the percentages shown in Table 12 and constituting 29% of the sum total of all well-preserved, complete or nearly complete forms recovered from the Port Campbell district during the past 20 years.

TABLE 12

Group	Shape Type	Number of Specimens	Percentage of total number of forms measured	
ELONGATED FORMS	Broad ovals	52	9·1	29·1%
	Narrow ovals	22	3·9	
	Oval plates	11	1·9	
	Elongated bowls	9	1·6	
	Elongated cores	6	1·1	
	Boats	29	5·1	
	Canoes	8	1·4	
	Dumb-bells	13	2·2	
	Teardrops	16	2·8	
ROUND FORMS	Buttons, lenses, round cores, etc.	405		70·9%

Curvature of Surfaces

The shapes of the elongated australites dealt with in Part II of the study of curvature-size relationships in australites are depicted in sketch form in Fig. 26. The outlines and curvature of the two surfaces, anterior and posterior respectively, were determined in a manner comparable with that already described in Part I. The method of obtaining the radii of curvature, the depth values and the diameter values, and standardizations of the method of measurement follow the technique already outlined in Part I of this study.

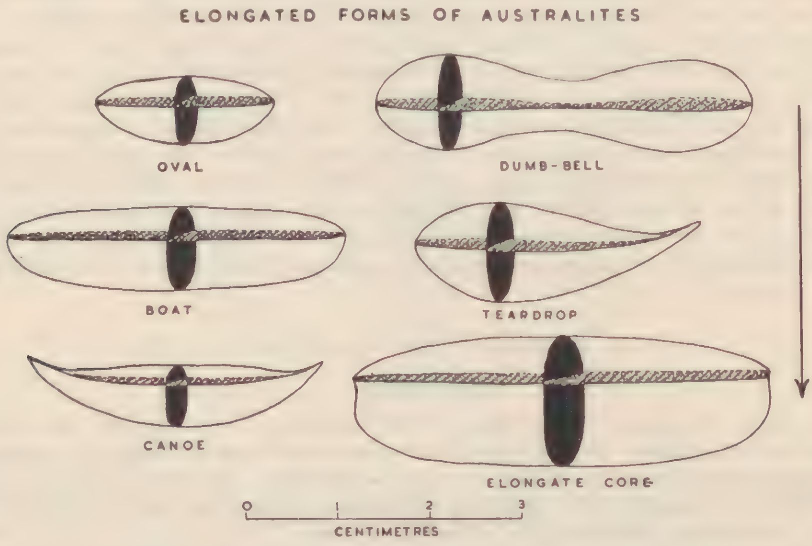


FIG. 26.—Sketch diagrams of the elongated forms of the Port Campbell australites. Posterior surfaces are those at the top of each sketch. (Arrow indicates direction of propagation through the earth's atmosphere.)

As in Part I, the flange dimensions have been omitted from depth, diameter and radius of curvature of front surface measurements, so that the curvature and size

relationships of the body portions of elongated australites could be directly compared in flanged and non-flanged forms alike.

Whereas there are larger numbers in each shape type of the round forms of the Port Campbell australites, this condition is not so satisfactorily realized among the elongated forms. Hence for the purposes of statistical significance the determined values such as depth, diameter, radii of curvature, etc., of each shape type of the elongated forms have been assembled together in kind, in constructing the frequency polygons, although individual values for each member of each particular shape type have been depicted in the scatter diagrams.

The same abbreviations introduced for the terminology of the round forms in Part I of this study are also utilized herein for the elongated australites, except that in place of diameter the terms width (Wi) and length (Le) are employed. In addition, the abbreviations L.S. and T.S. are used in some of the tables to connote measurements made about the two unequal diameters (Wi) and (Le) of the elongated forms. In radius of curvature measurements of front (R_F) and back (R_B) surfaces, the abbreviation T.S. connotes measurements made in a plane containing the shorter diameter (Wi) and the depth (De) and thus normal to the longer diameter. L.S. connotes measurements made in a plane containing the longer diameter (Le) and the depth (De) and thus normal to the shorter diameter.

Among the less elongated of these australites, one diameter (a) is a little shorter than the other diameter (b) in the equatorial plane of broad oval-shaped forms, with both of these diameters (or axes) usually longer than the third axis (c) which is contained in the polar plane and represents the depth (or thickness) —see sketch of oval in Fig. 27. Therefore (a) = the width, (b) = the length, and (c) = the depth of elongated australites. The axis (b) is always greater than (a) and (c) except in "aerial-bomb" forms (*cf.* Fig. 27), where (c) is the longer axis and (a) and (b) are approximately equal. The axis (a) is often greater than, but sometimes approximately equal to (c) in all elongated forms except "aerial-bomb"-shaped forms.

The more elongated australites such as the narrow ovals, the boats, canoes, dumb-bells and teardrops have the axis (b) much longer than axes (a) and (c) (*cf.* boat in Fig. 27), usually in the proportion of 2 : 1, but sometimes, although rarely, up to 11 : 1.

Sections through (or silhouettes of) elongated forms such as ovals, boats and canoes, taken normal to the longer diameter (and thus containing the (a) and (c) axes), and sections through the bulbous portions of dumb-bells and teardrops, possess the same general characteristics as the radial sections taken through the back and front poles of the round forms of australites dealt with in Part I of this study. Like them, similar relationships occur between the arcs and radii of curvature of the front (R_F) and back (R_B) surfaces respectively. Thus they indicate that the posterior surface is most likely a residual portion of the original primary surface, while the anterior surface is again a secondarily developed surface. Cross sections (i.e. normal to the long diameter) of the original primary shapes were more or less circular, as for the primary shapes of the round forms of australites. Since the elongated forms have this type of cross section, and in addition a longer diameter, it seems probable that all the primary shapes of the elongated australites were originally prolate or oblate spheroids of revolution, some of which became modified at their birthplace, to provide dumb-bell- and teardrop-shaped forms. For the majority of the elongated australites, the longer diameter is normal to the direction of propagation through the earth's atmosphere, and it is usually the axis (c), corresponding to the depth line which is in line with the direction of

earthward flight. Only in the rare "aerial-bombs" which retain a circular cross section normal to the longer (c) axis does the longer axis appear to have been arranged along the line of propagation (*cf.* Fig. 27).

Sections represented by planes containing the longer diameter (b-axis) and the depth (c-axis) reveal that the arcs of curvature along the (b) axis direction seldom correspond exactly to the circular arcs of curvature such as are provided by radial sections through round forms and by cross sections through elongated forms of the australites. More often they provide arcs of curvature suited to somewhat flattened spheroids. Such curvatures are usually steeper towards equatorial regions of the elongated forms, and often much flatter in the polar regions (*cf.* sketch of boat in Fig. 27).

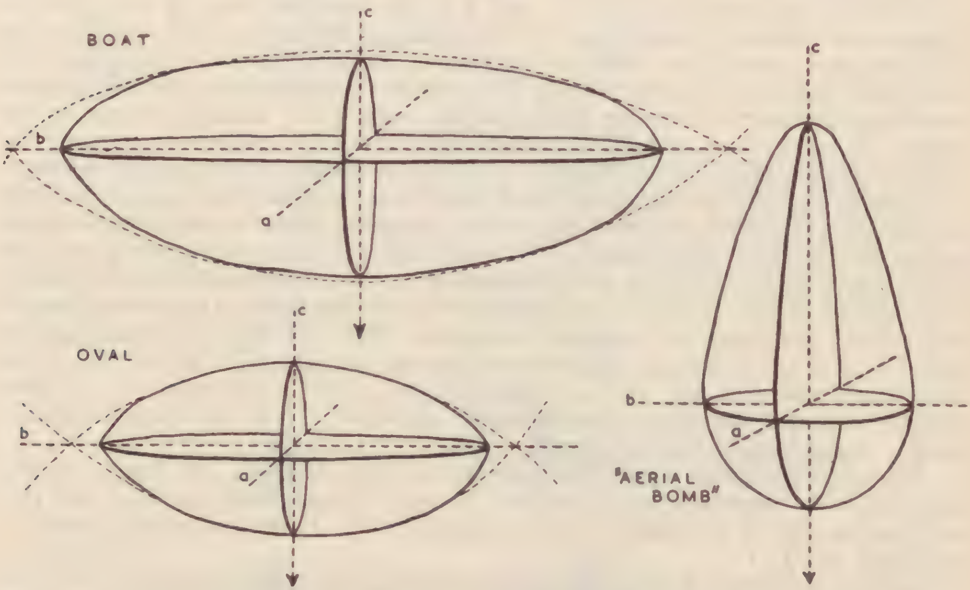


FIG. 27.—Sketches of boat-, oval- and "aerial-bomb"-shaped Port Campbell australites showing axial positions.

In Fig. 27, (a) is the shorter axis representing the width (Wi) in boats and ovals, while (b) is the longer axis representing the length (Le), and (c) the short vertical axis representing the depth (De) or thickness. In the "aerial-bomb" sketch, the (c) axis is the longer axis, while the (a) and (b) axes are approximately of equal length. The broken curved lines represent the arcs of curvature of circles constructed about posterior and anterior surfaces respectively. The arrows indicate the direction of travel of these forms through the earth's atmosphere, and the posterior surface is placed at the top of each sketch.

In some of the oval-shaped Port Campbell australites, particularly the broad ovals in which the longer and shorter diameters are not greatly different, it has been found that R_F for a given form may remain nearly the same in the two positions at right angles—i.e., one position normal to the longer diameter and the other position normal to the shorter diameter. Such forms reveal small differences

in the R_B values and arcs of curvature for the two positions at right angles, i.e. these oval-shaped types are not far removed from the button-shaped australites.

Both the arcs of curvature for the two positions at right angles of both the posterior and the anterior surfaces of broad ovals coincide with portions of the arc of curvature of coaxal circles with collinear centres. But since the arc of curvature of each surface in the two positions at right angles coincide with only one-quarter to one-third of the arcs of curvature of the constructed coaxal circles, it cannot be maintained that each represents portion of the arc of curvature of a sphere. Rather do they seem to indicate derivation from a spheroid of revolution not far removed from the spherical shape. The more elongated forms such as narrow ovals, boats, etc., on the other hand, were no doubt derived from primary spheroids of revolution that were originally more distinctly oblate or even prolate in kind.

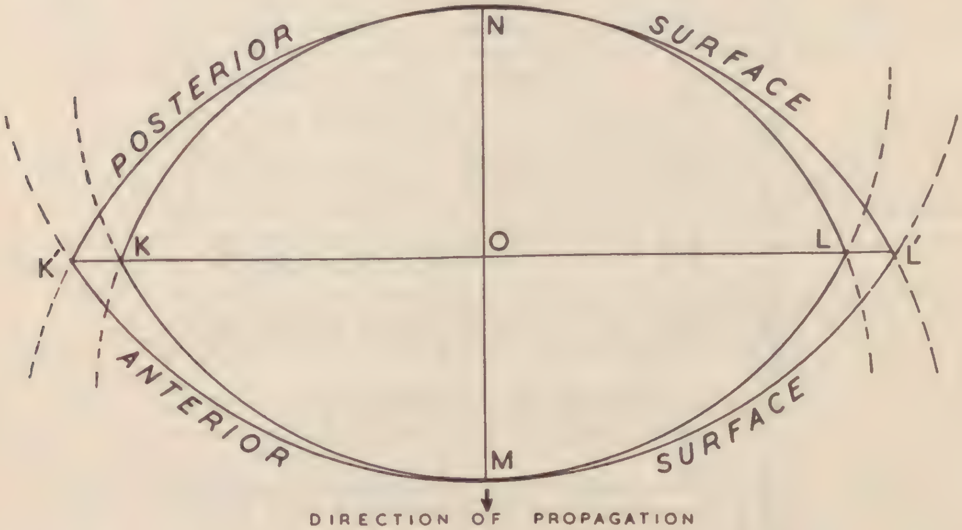


FIG. 28.—Cross sectional aspects of the two positions at right angles of an oval-shaped Port Campbell australite, superimposed on to a common line to illustrate the small differences in the two diameters and in the arcs of curvature of the two surfaces in the two positions.

Inasmuch as the ovals possess two diameters—one longer and one shorter—there are thus potentially two radical lines, if, for the purposes of illustration (Fig. 28), arcs of curvature of posterior and anterior surfaces in the two positions at right angles are tentatively regarded as portions of constructed circles, from which the actual arcs of curvature differ slightly, but nevertheless distinctly, compared with those for button-shaped australites. Thus, in Fig. 28, pairs of coaxal circles have been constructed, with one curve from one pair coinciding with its related curve from the other pair, meeting at the back pole (N), the other two curves from each pair meeting at the front pole (M). In other words, the arcs of curvature across the two diameters for the posterior surface are coincident at the back pole, and those across the two diameters for the anterior surface are coincident at the

TABLE 13

Ranges in Curvature-Size Measurements of 166 Elongated Forms of the Port Campbell Australites.

Shape Type	Percent of Elongated Forms	RF (mm.)		RB (mm.)		Ratio RB : RF		Depth (De) (mm.)	Length (Le) (mm.)	Width (Wi) (mm.)	Ratio De : Le	Ratio De : Wi	Ratio Wi : Le	OM (mm.)	ON (mm.)	Ratio OM : ON
		T.S.	L.S.	T.S.	L.S.	T.S.	L.S.									
Broad Ovals	31·5	5·0–15·5	5·5–22·0	3·0–12·0	7·0–23·0	1 : 0·76–1 : 2·0	1 : 0·5–1 : 1·43	2·5–10·0	10·0–24·5	7·5–19·0	1 : 1·4–1 : 4·0	1 : 1·1–1 : 2·7	1 : 1·1–1 : 1·4	1·5–7·5	1·0–7·0	1 : 0·33–1 : 1·0
Narrow Ovals	13·0	5·5–16·0	5·5–26·5	3·5–15·0	5·0–∞	1 : 0·75–1 : 2·14	1 : 0·46–1 : 3·60	3·5–13·5	11·0–36·5	7·5–21·5	1 : 2·2–1 : 4·0	1 : 1·3–1 : 2·4	1 : 1·5–1 : 1·9	1·0–5·0	2·0–9·5	1 : 0·63–1 : 3·5
Oval Plates	6·5	6·0–∞	8·5–∞	∞	10·5–∞	—	1 : 0·86–∞	1·0–2·5	9·0–16·5	6·0–14·5	1 : 4·0–1 : 11·0	1 : 3·6–1 : 9·5	1 : 1·1–1 : 1·5	—	—	—
Elongated Bowls	5·5	(2·5)*	2·0–6·5	—	—	—	—	1·0–4·5	7·0–12·0	5·0–7·5	1 : 2·0–1 : 7·7	1 : 1·6–1 : 6·0	1 : 1·2–1 : 2·4	—	—	—
Elongated Cores	3·5	10·0–20·0	11·5–29·0	11·0–22·0	14·0–36·5	1 : 0·75–1 : 0·91	1 : 0·71–1 : 1·37	12·5–16·0	22·5–42·5	20·0–33·0	1 : 1·5–1 : 2·7	1 : 1·3–1 : 2·1	1 : 1·1–1 : 1·6	4·0–10·0	5·5–10·0	1 : 0·61–1 : 2·12
Boats	17·5	4·5–14·0	5·5–43·0	3·5–12·0	22·0–∞	1 : 0·75–1 : 1·86	1 : 0·41–1 : 1·0	3·0–14·0	6·0–39·0	7·5–18·5	1 : 2·0–1 : 5·9	1 : 1·3–1 : 3·8	1 : 2·0–1 : 2·9	1·0–9·5	2·0–8·0	1 : 0·42–1 : 4·0
Canoes	5·0	3·0–6·5	(10·5)*	2·5–8·0	(26·5)*	1 : 0·72–1 : 2·6	(1 : 0·4)*	2·0–6·0	16·7–22·5	5·5–10·5	1 : 3·0–1 : 8·0	1 : 1·7–1 : 3·8	1 : 1·7–1 : 3·6	0·5–4·5	1·0–2·5	1 : 0·5–1 : 4·5
Dumb-bells	8·0	5·0–15·0	—	3·0–15·0	—	1 : 0·63–1 : 2·14	—	4·0–21·0	18·0–62·0	6·5–24·5	1 : 3·0–1 : 6·6	1 : 1·0–1 : 2·1	1 : 2·0–1 : 4·7	1·0–10·5	1·0–10·5	1 : 0·42–1 : 4·0
Teardrops	9·5	4·5–11·0	—	3·0–17·5	—	1 : 0·38–1 : 2·14	—	2·5–20·0	9·0–43·0	5·5–23·5	1 : 1·8–1 : 6·7	1 : 1·1–1 : 3·5	1 : 1·1–1 : 2·4	0·5–15·0	0·5–5·0	1 : 0·33–1 : 4·0

( )*—1 sp. only

front pole. Where such pairs of curves intersect, at K′ and L′, and at K and L in Fig. 28, the resultant radical lines K′L′ and KL represent the longer and shorter diameters respectively of the oval-shaped form.

Radii of Curvature, Depth, Width, Length and Intercept Values

The measured radii of curvature for anterior and posterior surfaces in the two positions at right angles indicated by Fig. 28, and also the depth, width and length, as well as the intercept (OM and ON) values, for the elongated forms of the Port Campbell australites are summarised in Tables 13 and 14, on the basis of division into the nine different shape types represented. Ranges in these values are set out in Table 13, and the calculated average values are listed in Table 14. The modes of the values obtained from the construction of the frequency polygons (Figs. 29-31, 33-35, 37, 38, 40 and 42-44) are tabulated in Table 15. For the purposes of the frequency polygons, and hence in Table 15, the various shape types comprising the elongated group of the Port Campbell australites have all been combined, because of low populations among a number of the types and no really large populations among the remaining types.

In Tables 13 and 14 the T.S. and L.S. columns refer to the two positions at right angles along which there are differences of R_F and of R_B. In the T.S. direction, the arcs of curvature were found to coincide relatively closely with the arcs of curvature of constructed circles, but in the L.S. direction a moderate percentage only approximately coincide. The infinity sign in Table 13 indicates forms with flat or almost flat surfaces.

Ratios of R_B to R_F, of De to Le, of De to Wi, of Wi to Le, and of the intercepts OM to ON are included in Tables 13 and 14. Where pairs of these factors are compared, R_B, De, Wi and OM have been retained at unity in the determination of the ratios.

Tables 13 to 15 show the variations in the ratios between selected pairs of these factors, and variations in the values of the measured factors, among the elongated forms of Port Campbell australites.

Radius of curvature values for both front (R_F) and back (R_B) surfaces are relatively similar for ovals, boats and dumb-bells, somewhat smaller for canoes and teardrops, and markedly increased for the elongated cores. Depth values reveal a considerable range. Length and width values for the broad and narrow ovals show a marked range, and the ratio between these two factors determines their classification; the ratios 1 : 1·1 to 1 : 1·4 represent broad ovals, and the ratios 1 : 1·5 to 1 : 1·9 represent narrow ovals. The narrow ovals are distinguished from the boat-shaped forms, which have a ratio of Wi : Le of from 1 : 2·0 to 1 : 2·9. Lengths of forms in the other shape types vary markedly, with long forms represented among the dumb-bells, teardrops and elongated cores. Variations of the intercepts OM and ON are generally comparable throughout the various types (Table 13), while the average values of these intercepts increase from oval plates and oval bowls, through canoes, teardrops, ovals, boats and dumb-bells, to the elongated cores.

Frequency Polygons and Scatter Diagrams

The following frequency polygons illustrate the distribution of the values of the various measurements made of the elongated Port Campbell australites without differentiation into the various shape types. This became necessary because of low populations in most of the nine shape types represented and little prospect of

TABLE 14

Average Values of Curvature-Size Measurements of 166 Elongated Forms of the Port Campbell Australites.

Shape Type	Percent of Elongated Forms	R_F (mm.)		R_B (mm.)		Ratio $R_B : R_F$		Depth (De) (mm.)	Length (Le) (mm.)	Width (Wi) (mm.)	Ratio De : Le	Ratio De : Wi	Ratio Wi : Le	OM (mm.)	ON (mm.)	Ratio OM : ON
		T.S.	L.S.	T.S.	L.S.	T.S.	L.S.									
Broad Ovals ..	31·5	8·5	11·0	8·0	12·0	1 : 1·15	1 : 0·95	7·0	16·0	13·0	1 : 2·3	1 : 1·9	1 : 1·2	3·5	3·5	1 : 1·2
Narrow Ovals ..	13·0	9·0	17·5	7·5	20·0	1 : 1·28	1 : 1	8·0	22·0	13·0	1 : 2·8	1 : 1·7	1 : 1·7	3·0	4·5	1 : 1·5
Oval Plates	6·5	7·0	11·5	∞	11·0	—	1 : 1·38	2·0	11·5	10·5	1 : 6·5	1 : 5·5	1 : 1·3	1·25	1·25	1 : 1
Elongated Bowls ..	5·5	(2·5)*	4·5	—	—	—	—	2·5	10·0	6·0	1 : 4·3	1 : 2·6	1 : 1·6	2·0	1·5	1 : 0·75
Elongated Cores ..	3·5	14·0	24·0	17·0	24·0	1 : 0·83	1 : 1	15·0	33·5	26·0	1 : 2·3	1 : 1·7	1 : 1·3	7·5	7·0	1 : 1·1
Boats ..	17·5	8·0	28·0	7·0	37·5	1 : 1·21	1 : 0·65	7·5	26·5	12·5	1 : 3·5	1 : 1·8	1 : 2·2	3·5	4·5	1 : 1·5
Canoes ..	5·0	5·0	—	6·0	—	1 : 1·22	—	4·0	19·0	8·0	1 : 4·5	1 : 2·3	1 : 2·4	2·5	1·5	1 : 1·74
Dumb-bells	8·0	8·0	—	7·0	—	1 : 1·4	—	8·5	34·0	12·0	1 : 4·4	1 : 1·4	1 : 3	3·5	4·5	1 : 2·0
Teardrops	9·5	7·0	—	7·5	—	1 : 1·15	—	4·0	19·0	8·0	1 : 3·9	1 : 2·3	1 : 1·7	3·0	2·0	1 : 1·3

( )*—1 sp. only.

TABLE 15

Modes of Frequency Polygons for Curvature and Size Measurements of Elongated Forms of Port Campbell Australites

Shape Group	R_F (mm.)	R_B (mm.)	Ratio $R_B : R_F$	Width (Wi) (mm.)	Length (Le) (mm.)	Depth (De) (mm.)	Ratio Wi : Le	Ratio De : Wi	Ratio De : Le	OM (mm.)	ON (mm.)	Ratio OM : ON
Elongated forms (All shape types grouped together)	8	6	1 : 1	10	12	6	1 : 1·5	1 : 1·5	1 : 2·5	3	4	1 : 1

sufficient numbers ever being found in an area that has been combed for australites for the past twenty years.

In the scatter diagrams (Figs. 32, 36, 39, 41 and 45 to 49) it has been possible to indicate most of the measured values of the separate shape types constituting the elongated Port Campbell australites, and to indicate the values for seven in most scatter diagrams and eight in a few of the scatter diagrams of the different shape types by utilizing conventional signs. Oval plates and elongated bowls can only be used in the scatter diagrams involving width, depth and length measurements (Figs. 36, 39 and 41) because they are either flat or bowl-like and hence not always amenable to R_B and R_F determinations.

In the preparation of both the frequency polygons and the scatter diagrams involving R_B and R_F values (Figs. 29, 30, 31, 32 and 46 to 49) only the measurements across the width, i.e. across axis (a) in Fig. 27, have been employed, since arcs of curvature determined for this position approximate more closely to the arcs of curvature of constructed circles than do the arcs of curvature determined across the length (i.e. across axis (b) in Fig. 27, sketches of boat and oval).

The values of the measurements of the intercepts OM and ON (Figs. 42, 43, 44 and 45) were determined from similar constructions to those from which the employed R_B and R_F values were determined (*cf.* columns headed T.S. in Tables 13 to 15).

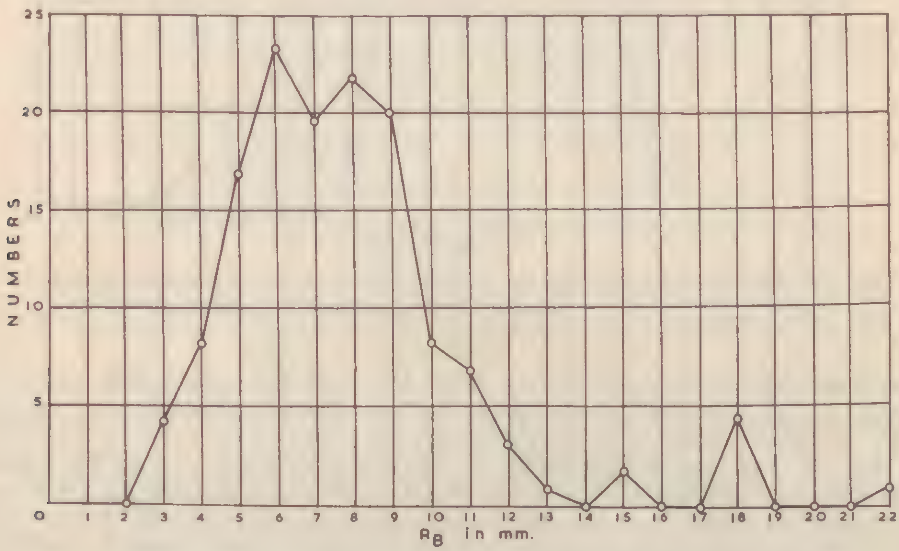


FIG. 29.—Frequency polygon illustrating distribution of radius of curvature of posterior surface (R_B) values for elongated shapes of the Port Campbell australites.

The distribution of the R_B values for the elongated Port Campbell australites, shown in Fig. 29, reveals a relatively wide range (2 to 22 mm.), but the greater numbers of specimens possess R_B values between 5 and 9 mm., with a marked mode at 6 mm. and a secondary peak in the polygon at 8 mm. The small trough in the polygon on the 7 mm. co-ordinate, however, has no especial significance.

The R_F values (Fig. 30) show a similar range to R_B values (Fig. 29), and likewise reveal prominent modes at 6 mm. and 8 mm., so that in T.S. sections

through elongated australites the indication is that R_B and R_F values are comparable in amount (*cf.* also Table 14), although there is a somewhat more significant trough in the polygon (Fig. 30) on the 7 mm. co-ordinate.

The ratio of R_B to R_F, plotted to the nearest 0·5 (Fig. 31), reveals that a preponderance of forms have a 1 : 1 ratio, while a significant number possess a ratio of 1 : 1·5, thus bearing out the above remarks concerning Figs. 29 and 30. Few specimens have ratios of 1 : 0·5, indicating R_B values twice as great as R_F values. Few specimens have ratios of 1 : 2·0 and 1 : 2·5, indicating R_F values two to two and a half times as great as R_B values. It can be seen from Table 13 that

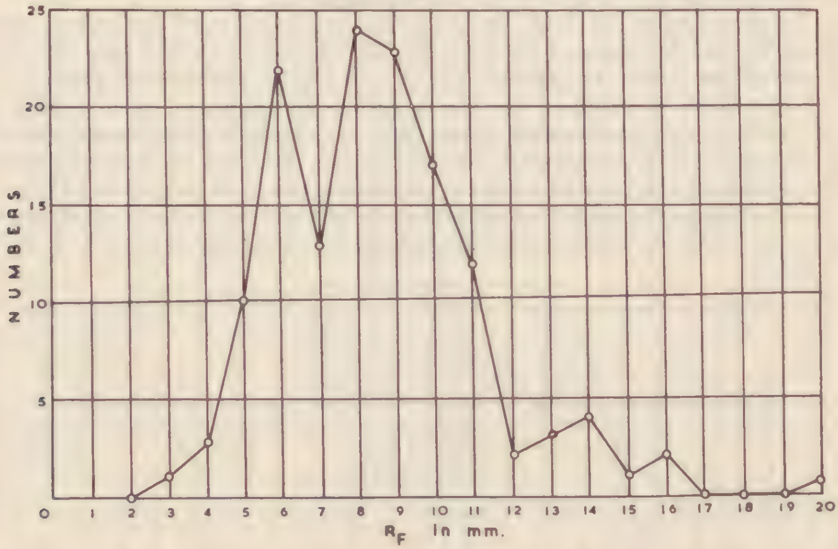


FIG. 30.—Frequency polygon illustrating distribution of radius of curvature of anterior surface (R_F) values for elongated shapes of the Port Campell australites.

occasional dumb-bells and teardrops have the lower ratios of 1 : 0·5, and a few broad and narrow ovals, a few canoes and occasional dumb-bells and teardrops have the higher ratios of 1 : 2·0 and 1 : 2·5.

Fig. 32, showing the relationships of individual R_B and R_F values for separate specimens of the different shape types, reveals a trend of increasing R_F values with increasing R_B values, both for the elongated group as a whole and for the component shape types constituting the elongated group of Port Campbell australites. As noted among the round forms dealt with in Part I of this study, likewise in the elongated group of these australites there occur numbers of specimens with the same R_B value (e.g. 8 mm.) having a range in R_F values (5 to 11·5 mm.), and numbers of specimens with the same R_F values (e.g. 9 mm.) having a range in R_B values (5 to 12 mm.). These, however, do not materially affect the general trends indicated for the group as a whole (*cf.* Fig. 32), and such variations are possibly accounted for in terms of the effects of differential ablation of (i) primary forms of originally similar size on the one hand, and (ii) primary forms of originally different size on the other hand. In other words, similar forms may be differently ablated to result in different arcs of curvature of the anterior surface,

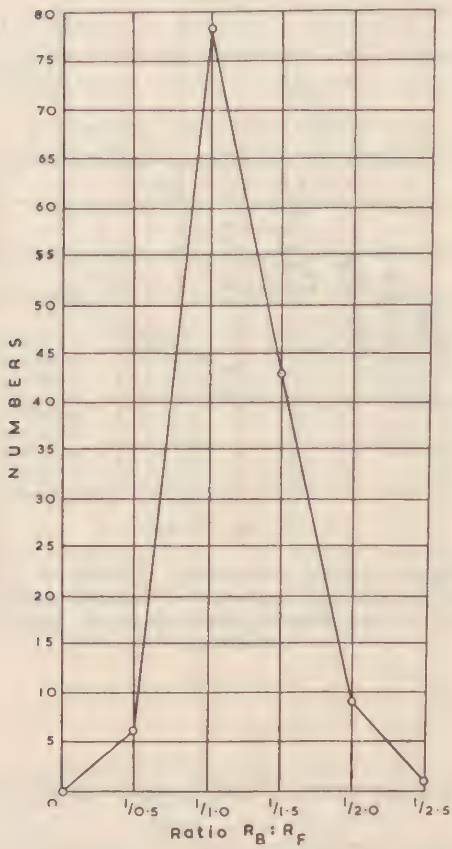


FIG. 31.—Frequency polygon illustrating distribution of $R_B : R_F$ ratios for elongated shapes of the Port Campbell australites.

while by the same process similar arcs of curvature can result for anterior surfaces on end shapes derived from different size primary forms.

The depth values plotted in Fig. 33, although showing a relatively wide range from 2 to 22 mm., are mainly concentrated between 4 and 10 mm., with a pronounced if not very significant mode at 6 mm. The depth values are therefore closely comparable with values for R_B and R_F. Most of the thinner forms (4 mm. and under) of the elongated Port Campbell australites occur in the canoe, teardrop, oval plate and elongated bowl shape types. Those of medium depth (4 to 10 mm.) are found among the oval- and boat-shaped types. The thicker forms comprise the elongate cores and one or two of each of the boat-, dumb-bell- and teardrop-shaped elongated australites.

The width values of the elongated australites, shown in Fig. 34, reveal a considerable range from 6 to 32 mm., but with most (92%) in the 6 to 18 mm. width range, where there is a marked mode at 10 mm. and a slight shortage of specimens of 14 mm. width.

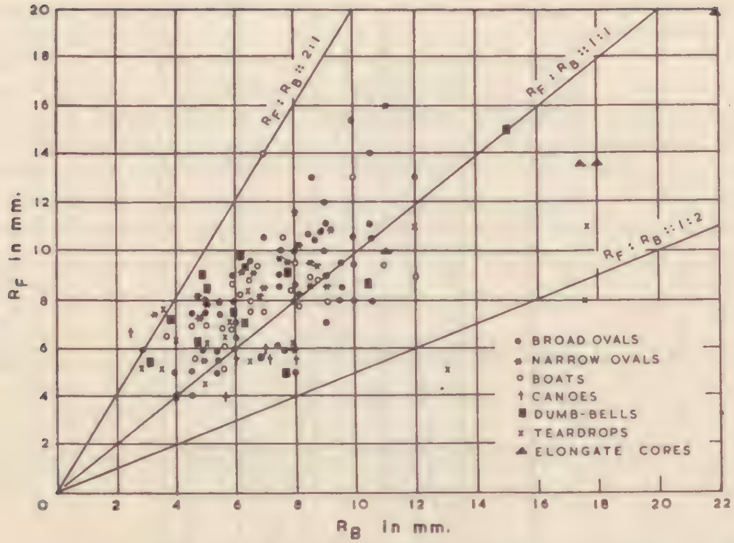


FIG. 32.—Scatter diagram showing relationship of radius of curvature of posterior surface (R_B) values to radius of curvature of anterior surface (R_F) values for individual specimens of the different shape types of elongated Port Campbell australites.

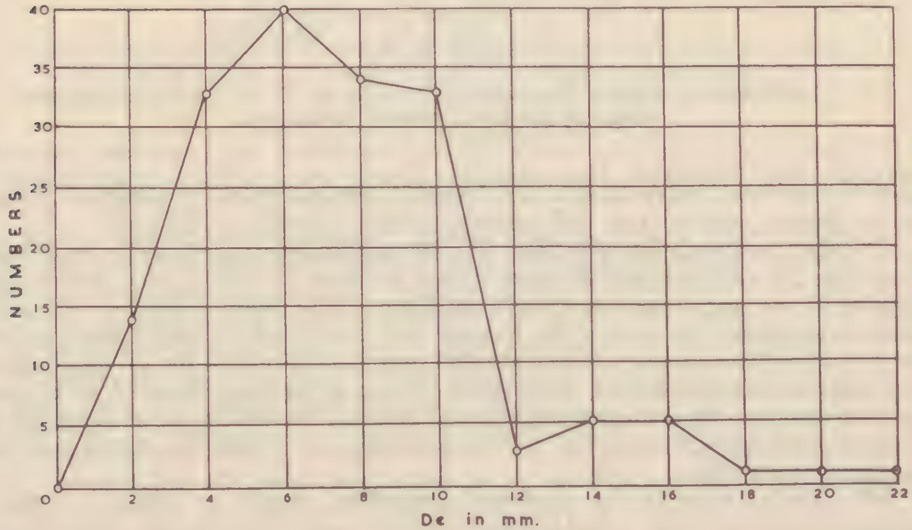


FIG. 33.—Frequency polygon illustrating distribution of depth (De) values for elongated forms of the Port Campbell australites.

Reference to Tables 13 and 14 reveals that the widest forms occur among the elongated cores, and the narrowest among the elongated bowls, canoes and teardrops. The bulbous portions of one or two of each of the dumb-bells and teardrops, however, possess relatively great width values, being much larger than average size.

The ratio between depth (De) and width (Wi) of the elongated australites (Fig. 35) brings out the fact that a considerable number (80%) of these forms

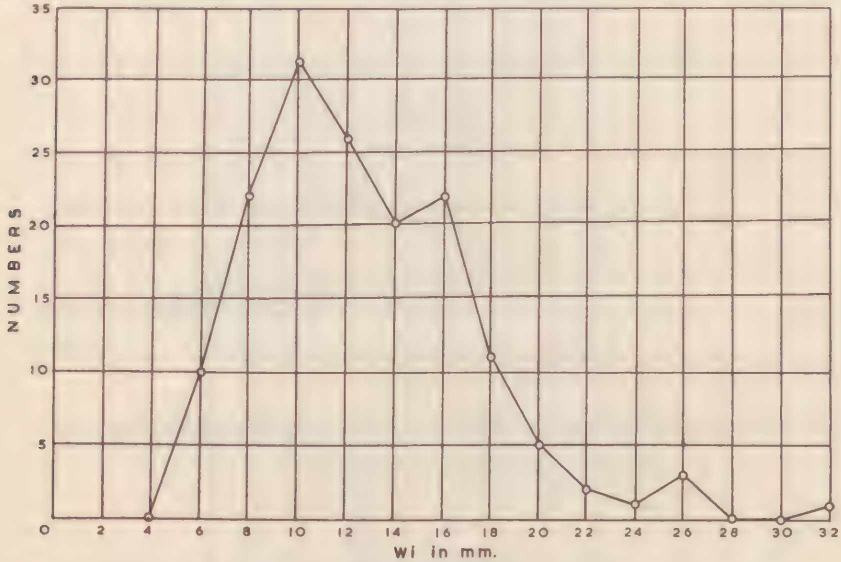


FIG. 34.—Frequency polygon showing distribution of width (Wi) values for elongated forms of the Port Campbell australites.

have width values one and a half to twice as great as their depth values. Only a few (4%) reveal a 1 : 1 ratio, a somewhat larger number (10%) possess a width value 2·5 times as great as that of depth, and a relatively small number reveal ratios of 1 : 3·0, 1 : 3·5 and 1 : 4·0.

The relationships between individual values of depth and width measurements are shown in Fig. 36. Neglecting the relatively thin oval plates and elongated bowls, it can be seen from Fig. 36 that there is a general increase in depth with increase in width. The depth and width values plotted for the dumb-bells and teardrops refer solely to their bulbous portions. Depth and width values tend to increase throughout the elongated australite group from canoes and teardrops, through dumb-bells and narrow ovals, broad ovals and boats, to the thicker and wider elongated cores. Occasional teardrops and dumb-bells occur among the higher values for depth and width. The width values of the oval plates and elongated bowls increase from 5 mm. to nearly 14 mm. for only a narrow range (1 to 4 mm.) in depth (i.e. thickness) values.

The distribution of the length values (Fig. 37) is a relatively widespread one, with a range from 6 to 62 mm. The maximum number (17%) of the total measured have length values of 12 mm., and lesser numbers (each approximately 10%) have lengths of 16 and 20 mm.

The ratios between depth (De) and length (Le) provide a relatively uniform distribution, as shown by Fig 38, where it can be seen that the mode of the polygon is on the 1 : 2·5 co-ordinate. Approximately 60% of the specimens have ratios between 1 : 2 and 1 : 3, so that length values are thus usually two to three times as great as depth values, but may be up to eight times as great. A few are only 1·2 to 1·5 times as great, and these are found among the broad oval shape type.

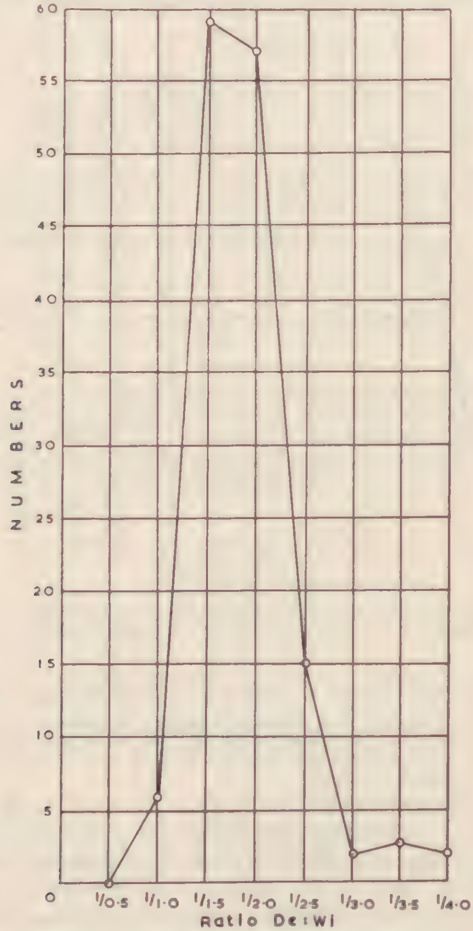


FIG. 35.—Frequency polygon showing Ratio De : Wi-Numbers relationships for elongated shapes of the Port Campbell australites.

The relationships between De and Le values for the individual specimens of these elongated australites reveal a fairly wide scatter (Fig. 39) when the group as a whole is considered. For any particular shape type comprising the elongated group, however, there is observed a marked trend of increasing depth with increasing length, and this trend for each shape type is confined to relatively narrow zones of distribution. This is well shown independently by the broad ovals, by the narrow

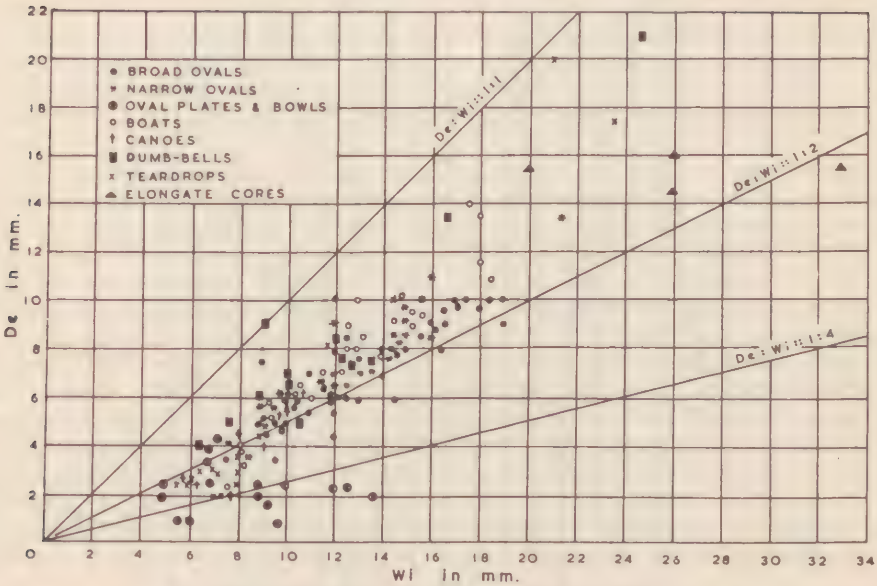


FIG. 36.—Scatter diagram showing relationship of depth (De) and width (Wi) values for individual specimens of the different shape types constituting the group of elongated Port Campbell australites.

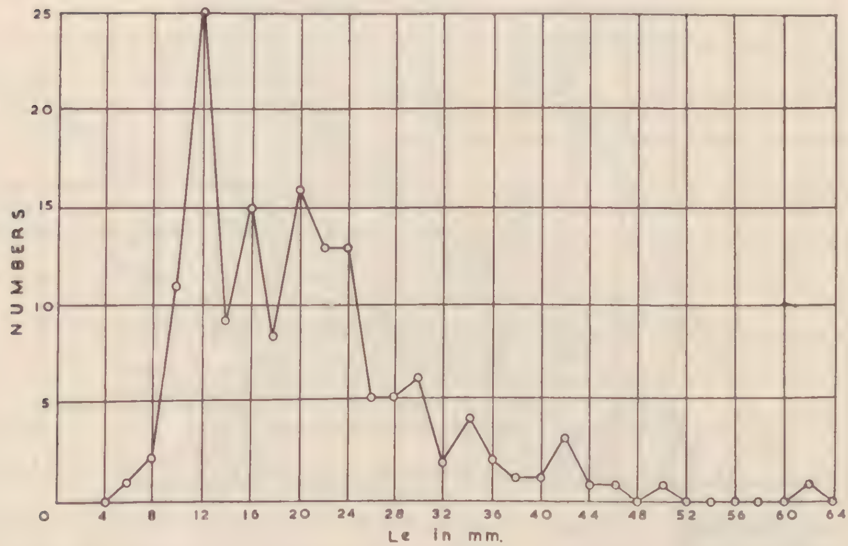


FIG. 37.—Frequency polygon showing distribution of length (Le) values for elongated shapes of the Port Campbell australites.

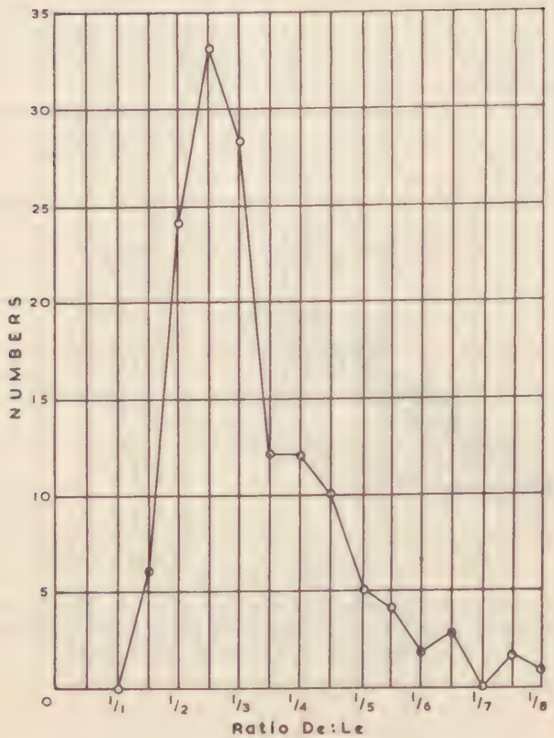


FIG. 38.—Frequency polygon showing Ratio De : Le - Numbers relationships for elongated shapes of the Port Campbell australites.

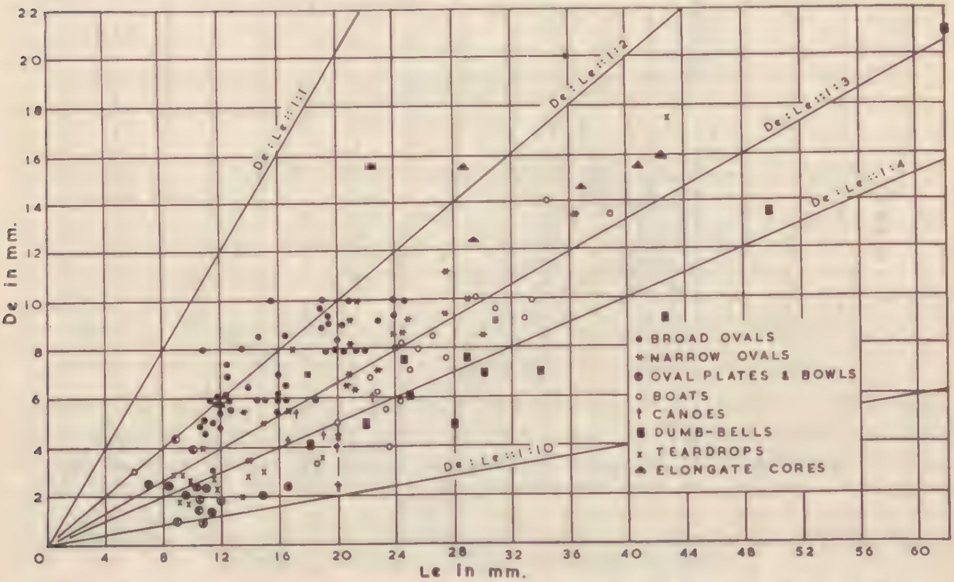


FIG. 39.—Scatter diagram showing relationship of depth (De) and length (Le) values for individual specimens of the different shape types constituting the elongated group of Port Campbell australites.

ovals, and by the boats and dumb-bells in Fig. 39. Among the smaller depth values, however, there is little change to be observed as length increases among the oval plates and elongated bowls. Much the same applies to the teardrops. Among the greater depth values there is also observed a small range of depth (12·5 to 16 mm.) for a considerable range in length values (22 to 43 mm.) of the elongated cores.

The distribution of width-length relationships is indicated by the ratios plotted in Fig. 40. The ratios have been calculated to the nearest 0·5, so that a considerable number (28%) fall on the 1 : 1 co-ordinate, due to many specimens of the broad ovals, together with the oval plates and elongated bowls, possessing length and width values separated by only 1 to 2 mm. It has been shown in an earlier publication (Baker, 1955) that although such differences between width and length values are small, they are nevertheless significant, inasmuch as the differences comprise 10% and over (up to 16%) of the total measurements of these relatively small objects. For this reason, such specimens have been classified with the elongated rather than with the round form group of the Port Campbell australites.

The mode of the frequency polygon (Fig. 40) occurs on the 1 : 1·5 co-ordinate, and this is due to the considerable number of oval-shaped forms which have length and width dimensions which provide ratios indicating length 1·2 to 1·5 times as great as width values. A significant number of specimens providing ratios Wi : Le :: 1 : 2 are composed typically of the boat-shaped forms, accompanied by

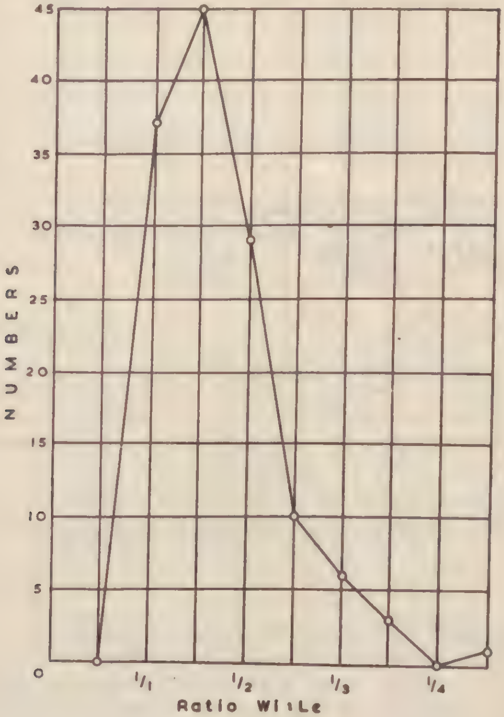


Fig. 40.—Frequency polygon showing Ratio Wi : Le-Numbers relationships for elongated shapes of the Port Campbell australites.

a few teardrops and dumb-bells. Higher ratios of Wi : Le :: 1 : 2·5 and over are found largely among the canoe- and dumb-bell-shaped australites.

The distribution of width and length values of individual elongated Port Campbell australites, shown in Fig. 41, reveals a generally increasing trend of length values with increased width in each of the shape types comprising the elongated group. This trend is rather better pronounced and confined to rather a narrower zone than the depth-length relationships (Fig. 39). The crowding of specimens near the Wi : Le :: 1 : 1 gradient line (Fig. 41) is due to the broad oval and oval plate-shaped types in which length values are not greatly in excess of width values. Only in certain forms, such as the dumb-bells, are the length values as much as three to six times as great as the width values.

In the distribution of the OM intercept values for elongated forms of australites there is a prominent mode (Fig. 42) on the 3 mm. co-ordinate (as likewise found for the round forms discussed in Part I of this study). Thirty per cent of the specimens possess OM values of 3 mm., while significant numbers of specimens (23% and 20% respectively) possess OM values of 2 mm. and 4 mm.

In the distribution of the ON intercept values (Fig. 43) the mode occurs on the 4 mm. co-ordinate, for which value 20% of the specimens are responsible.

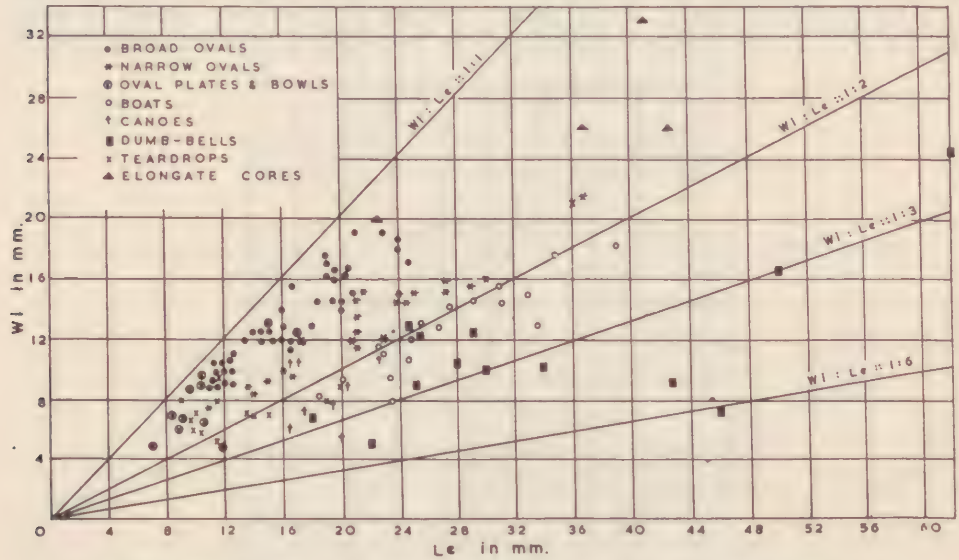
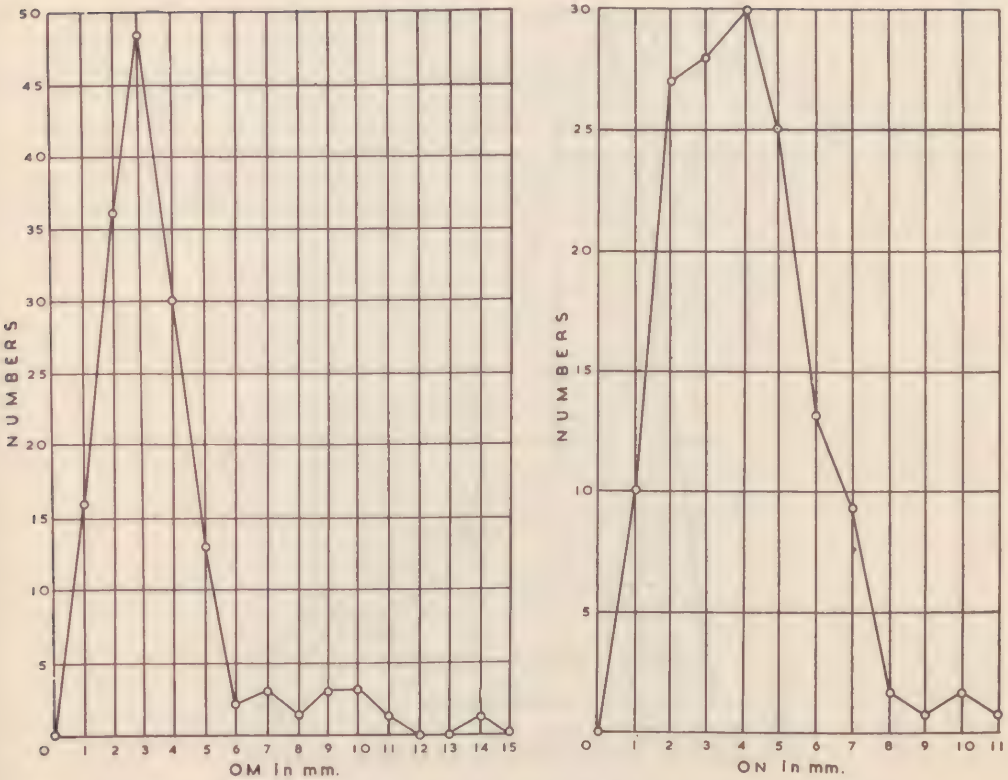


Fig. 41.—Scatter diagram showing relationship of width (Wi) and length (Le) values for individual specimens of the different shape types constituting the group of elongated Port Campbell australites.

There are, however, significant numbers of specimens with ON values of 2, 3 and 5 mm., for which 17%, 18% and 16% of the specimens are responsible.

The ratio OM : ON values show a relatively even distribution (Fig. 44) and therefore only slight skewness of the frequency polygon. Thirty per cent of the forms reveal unit ratio, while 18% have ratios of 1 : 0·5, 24% have ratios of 1 : 1·5, and 14% have ratios of 1 : 2. The remainder range from ratios of 1 : 2·5 to 1 : 4·0.



FIGS. 42 and 43.—Frequency polygons showing Intercept OM - Numbers and Intercept ON - Numbers relationships for elongated forms of the Port Campbell australites.

The plotted OM and ON values for individual specimens reveal a fairly wide scatter (Fig. 45), but there is nevertheless a general indication that ON values increase with increase in OM values, this trend being best shown among the various shape types by the majority of the dumb-bells and some of the ovals and boats.

In Figs. 46 to 49, showing the relationships of depth and width values to the radii of curvature (R_B and R_F) values of the posterior and anterior surfaces of the elongated australites, R_B and R_F have been determined from cross sectional aspects normal to the length. It can be seen that much wider scatters occur for De-R_B and De-R_F (Figs. 46 and 48) than for Wi-R_B and Wi-R_F (Figs. 47 and 49) relationships. In all of these four diagrams there is observed a general tendency for both De and Wi to increase as values of R_B and R_F increase, and this is most pronounced in Wi-R_B and Wi-R_F relationships, where all shape types except the canoes, of which there are relatively small numbers, show regular increases of both factors in each comparison (Figs. 47 and 49), and where the distributions are confined to rather narrow zones.

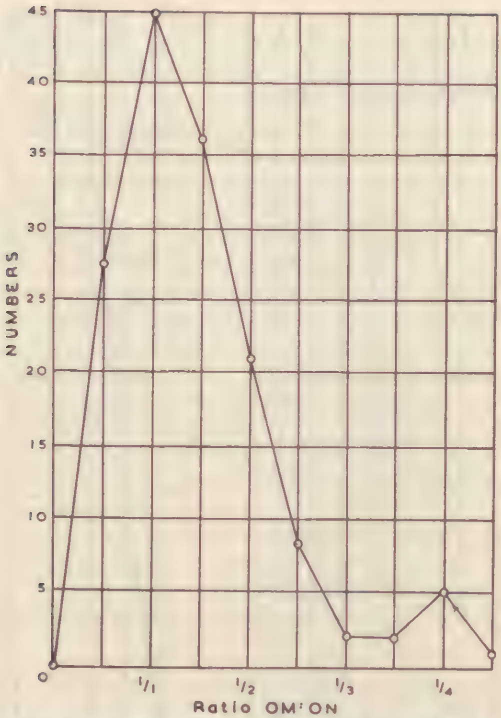


FIG. 44.—Frequency polygon showing Ratio OM : ON - Numbers relationships for elongated shapes of the Port Campbell australites.

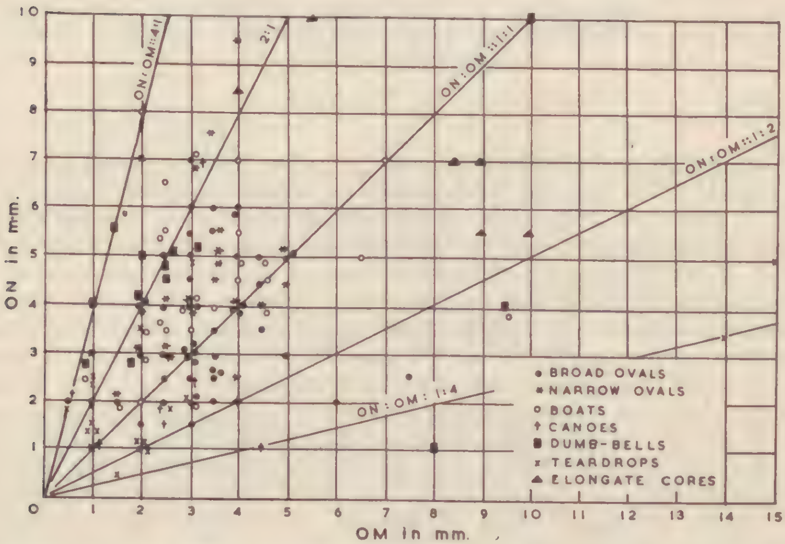


FIG. 45.—Scatter diagram showing relationships of the intercept values, OM and ON, for individual specimens of the different shape types constituting the group of elongated Port Campbell australites.

Irregularities in the relationships between depth values and the R_B and R_F values arise from the fact that the centres of the various arcs of curvature for different specimens are variously located on the depth line (see NM in Fig. 28) or its extension. The arcs of curvature of the elongated australites, when considered solely across their shorter diameter (i.e. width), closely approximate to the arcs of curvature of constructed circles, but not with the degree of perfection observed for the round form group of the Port Campbell australites. Arcs of curvature across the longer diameter (i.e. length) seldom tally with the arcs of curvature of constructed circles.

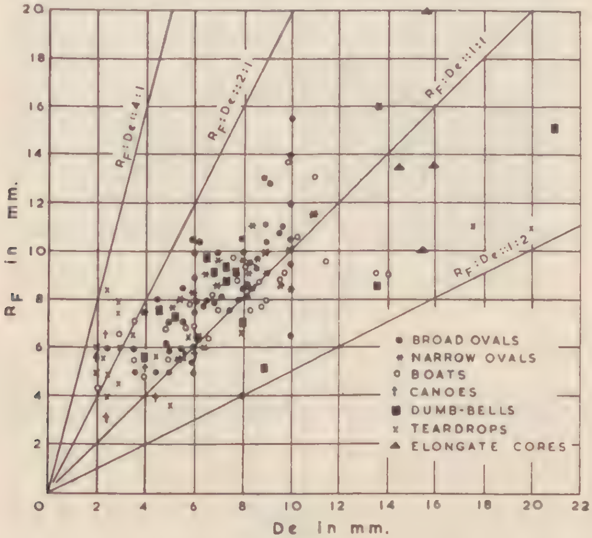


FIG. 46

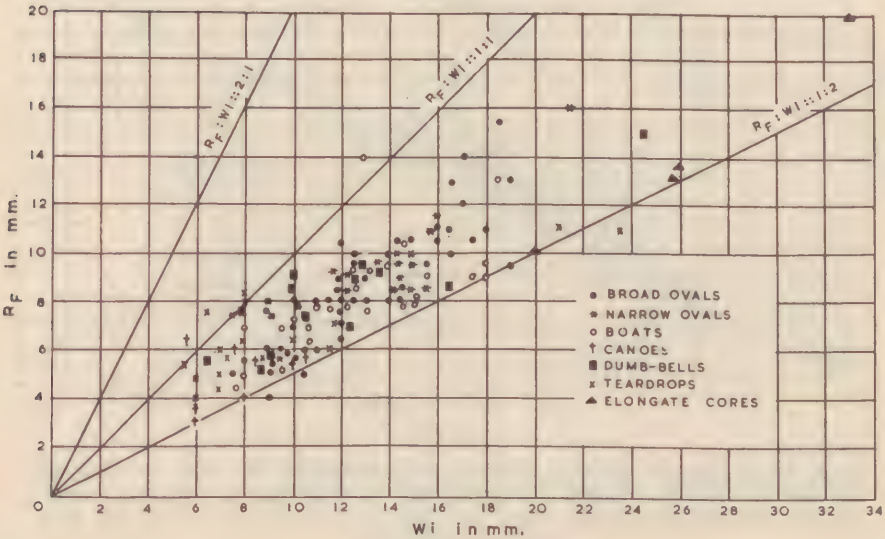


FIG. 47

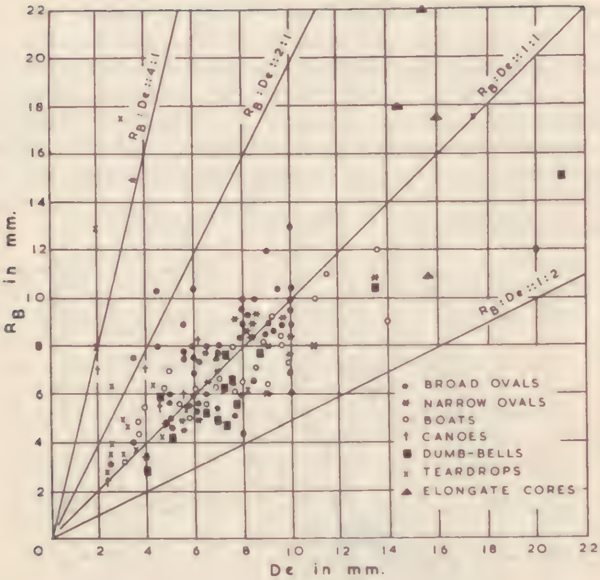


FIG. 48

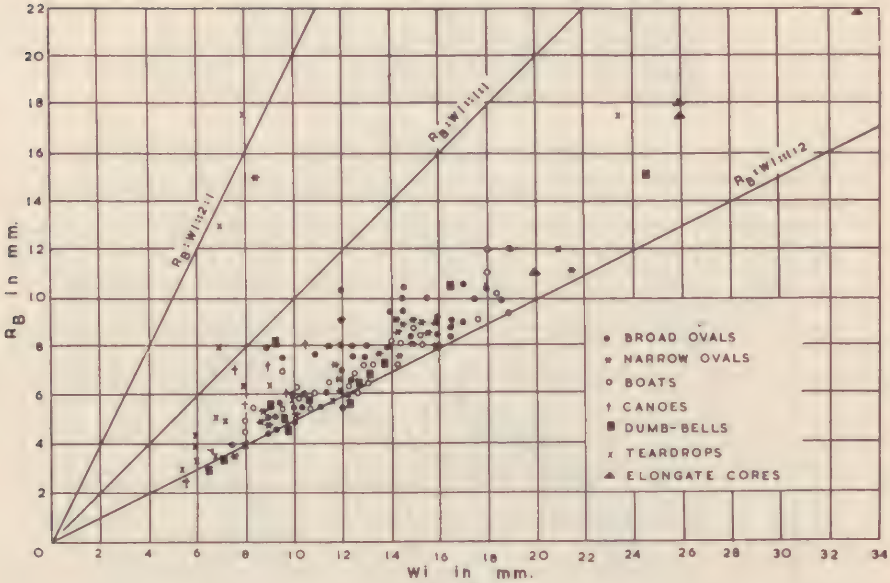


FIG. 49

FIGS. 46-49.—Scatter diagrams showing relationships of the radii of curvature (R_B and R_F) values to depth (De) and width (Wi) values for individual specimens of the different shape types constituting the group of elongated Port Campbell australites.

Conclusions

The primary forms from which the secondary shapes of the elongated Port Campbell australites were derived were all originally forms assignable to the limited group of elongated figures of revolution, namely oblate spheroid, prolate spheroid, apioid and dumb-bell. The derivation of the secondary end shapes from ablation and fusion-stripping of primary forms travelling through the earth's atmosphere at ultra-supersonic speeds has already been referred to in Part I of this study.

Frequency polygons and scatter diagrams representing the measurements of the curvature and size of the elongated australites from Port Campbell serve to show the differences between their dimensions and those of the round forms. They also show the general similarity between the arcs and radii of curvature of end-on aspects of the elongated forms and side aspects of the round forms, a trend which is also evident in the smaller population of australites obtained from the Nirranda district (Baker, 1955). Such trends in both the Port Campbell and the Nirranda australites indicate that both have been subjected to comparable amounts of size reduction by similar processes that modified the original primary forms. From a limited number of original shapes were produced limited numbers of modified shape types (i.e. secondary forms) as now found.

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9

COMPARISONS OF THE ACTUAL TIDES OF HOBSON'S BAY WITH THOSE PREDICTED FROM HARMONIC CONSTANTS

By J. E. Bradley

[Read 9 December 1954]

In order to determine the errors to be expected when using the Tidal Predictions for Williamstown (Hobson's Bay) issued by the Liverpool Observatory and Tidal Institute for the Melbourne Harbor Trust Commissioners, comparisons were made of the times and heights of all high and low waters predicted for the year 1953 with the times and heights of the corresponding tides recorded by the self-registering tide gauge situated at the shore end of Ann Street Pier, Williamstown.

The comparisons appear in the following tables. The differences are believed to be due almost entirely to meteorological causes. Analyses of weather conditions and their related effects on the tides have not been made. It is estimated in a general way from experience during the last thirty years that in very hot or northerly and easterly weather the tides are lower than usual and occur earlier than predicted. The reverse occurs in stormy weather during westerly or southerly gales.

The entrance to Port Philip is a little less than two nautical miles wide, and the tidal area of Port Philip is about 725 square miles. Because the entrance is so narrow in relation to the area enclosed, the mean tidal range in Port Philip is only about 1 ft. 8 in., consequently the percentage divergence of the actual from the predicted tide produced by a wind of given velocity in Port Philip is much greater than it would be in an inlet of similar area in which the tidal range was, say, 20 ft.

The lowest high tide recorded was on 27 July 1923, a height of 5 in., and the highest low tide was on 30 November 1934, a height of 3 ft. 8¾ in., during a violent and prolonged storm (when the following high tide rose to 6 ft. 6 in.). In stormy weather the tide rises with a series of surges having a period of between one to two hours or less. The heights of these surges vary between 6 in. and 10 in.

References

Bradley, J. E., 1949. Tides of Hobson's Bay. *Proc. Roy. Soc. Vic.*, 56: 113-122.

TABLE 1

Frequency of Differences in Time between predicted Tides and those occurring at Williamstown (1953)

	HIGH WATER TIMES							LOW WATER TIMES						
	0 min. to 10 min.	10 min. to 20 min.	20 min. to 30 min.	30 min. to 60 min.	60 min. to 90 min.	Over 90 min.	Total number of Tides	0 min. to 10 min.	10 min. to 20 min.	20 min. to 30 min.	30 min. to 60 min.	60 min. to 90 min.	Over 90 min.	Total number of Tides
January . .	30	13	8	8	1	0	60	13	20	10	15	2	0	60
February . .	24	11	5	11	3	0	54	15	10	13	15	1	0	54
March	18	16	11	12	3	0	60	12	13	13	20	2	0	60
April	20	16	9	10	2	1	58	20	12	8	16	2	0	58
May	19	14	12	13	2	0	60	19	15	8	14	4	0	60
June	16	15	13	10	4	0	58	14	18	14	8	3	1	58
July	17	15	8	16	3	1	60	20	18	9	6	4	2	59
August . .	22	14	9	15	—	—	60	16	18	10	14	1	1	60
September . .	21	12	6	13	4	2	58	16	11	10	11	7	3	58
October . .	22	12	15	9	2	—	60	19	18	9	12	2	—	60
November . .	19	6	16	13	3	1	58	16	13	9	17	3	—	58
December . .	20	15	9	13	2	1	60	17	16	6	16	4	1	60
Total Tides for Year . .	248	159	121	143	29	6	706	197	182	119	164	35	8	705
Percentage of Whole . .	35·13	22·52	17·14	20·25	04·11	0·85	100	27·94	25·81	16·88	23·26	04·97	01·14	100

TABLE 2

Frequency of Differences in Height between predicted Tides and those occurring at Williamstown (1953)

	HIGH WATER HEIGHTS								LOW WATER HEIGHTS							
	0 in. to 3 in.	3 in. to 6 in.	6 in. to 12 in.	12 in. to 18 in.	18 in. to 24 in.	24 in. to 30 in.	Over 30 in.	Total number of Tides	0 in. to 3 in.	3 in. to 6 in.	6 in. to 12 in.	12 in. to 18 in.	18 in. to 24 in.	24 in. to 30 in.	Over 30 in.	Total number of Tides
January ..	36	22	2	—	—	—	—	60	45	13	2	—	—	—	—	60
February ..	34	6	10	4	—	—	—	54	36	10	8	—	—	—	—	54
March	32	17	11	—	—	—	—	60	36	15	8	1	—	—	—	60
April	17	14	21	6	—	—	—	58	20	12	23	3	—	—	—	58
May	28	14	11	5	1	1	—	60	27	15	12	3	3	—	—	60
June	21	13	11	8	5	—	—	58	22	13	12	6	5	—	—	58
July	22	12	14	11	1	—	—	60	20	16	12	9	2	—	—	59
August ..	16	24	16	4	—	—	—	60	21	24	13	2	—	—	—	60
September ..	20	9	22	5	2	—	—	58	22	14	15	6	1	—	—	58
October ..	21	22	14	2	1	—	—	60	32	19	7	2	—	—	—	60
November ..	20	8	25	4	1	—	—	58	20	12	22	4	—	—	—	58
December ..	14	18	23	3	2	—	—	60	22	24	12	2	—	—	—	60
Total for Year	281	179	180	52	13	1	—	706	323	187	146	38	11	—	—	705
Percentage of Whole ..	39·80	25·35	25·49	7·36	1·85	0·15	—	100	45·82	26·52	20·71	5·39	1·56	—	—	100

10

THE RANGE AND EXTINCTION OF *DIPROTODON MINOR* HUXLEY

By Edmund D. Gill, B.A., B.D.

[Read 9 December 1954]

Interesting and varied though the present marsupial fauna of Australia is, the Pleistocene fauna was even more so, for many whole genera have become extinct since then. Among these genera is *Diprotodon*, one species of which (*optatum*) was the largest marsupial that ever lived. Four species have been listed by Simpson (1930) in his catalogue, viz.:

Diprotodon optatum (= *D. australis*) Owen 1838
D. longiceps McCoy 1865
D. bennettii Owen 1877
D. minor Huxley 1862

The last-named is a comparatively diminutive form, and little is known about it. The species was originally described from some teeth found at Gowrie on the Darling Downs in Queensland (Huxley 1862). De Vis (1888) extended our knowledge by describing some teeth from King's Creek on the Darling Downs. Stirling and Zietz (1900) recorded remains of a small *Diprotodon* from Lake Callabonna in South Australia which they "referred provisionally and inclined to think definitely" to *D. minor*. Dennant and Kitson (1903) included it as such in their faunal lists. In more recent years, Longman (1924) has described a mandible of *D. minor* from the Darling Downs, and indicated mandibular differences between this species and the huge *D. optatum*. In 1929 Longman reported receipt at the Queensland Museum of a mandibular fragment from Murgon, thus extending the range of *D. minor* further north.

Victorian Occurrence

From under basaltic tuff at Blind Creek near Camperdown in Western Victoria, Grayson and Mahony (1910) recorded vertebrate fossils. This material is now in the National Museum of Victoria. It was collected by Mahony and includes *Diprotodon minor* and a giant kangaroo. The *Diprotodon* species is represented by the upper incisor tooth (P 16155) shown in Fig. 1. That the tooth is that of a mature animal and not a juvenile is shown by its degree of wear. Its measurements are:

Length in straight line 7·8 cm.
following curvature 8·8 cm.

Width at posterior limit of area of wear 2·4 cm.
at root end of tooth as preserved 2·9 cm.

Thickness at posterior limit of area of wear 1·4 cm.
at root end of tooth as preserved 1·7 cm.

Pulp Cavity as seen at root end of tooth as preserved is lenticular in cross-section and measures 1·4 cm. by 0·4 cm.

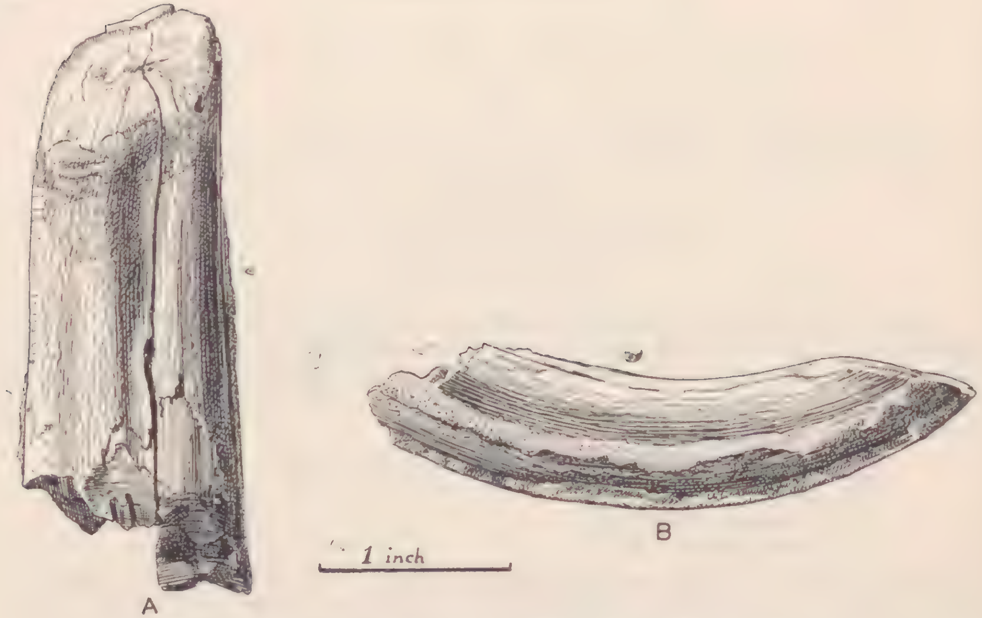

FIG. 1.—*Diprotodon minor* Huxley from Blind Creek, Western Victoria.
A. Back or lingual surface of upper incisor, showing area of wear.
B. Side view of same.
Drawing by G. Browning.

The tooth has the typical flattish cross-section of a *Diprotodon* upper incisor. Along both the front and back of the tooth is a shallow yet well-defined groove. The enamel on the front surface has what Krefft (1873) has aptly called a "worm-eaten appearance". It might be suspected that bones of a smaller *Diprotodon* could be confused with those of *Nototherium*, but in the case of the first pair of upper incisors those of *Diprotodon* are readily distinguished from those of *Nototherium* because the former are chisel-like while the latter are conical. This is the first time that the upper incisor of *D. minor* has been described.

New South Wales Occurrences

The finding of *Diprotodon minor* in Victoria as well as in Queensland presumed that this animal lived also in the intervening area of New South Wales. Through the kind co-operation of Dr. A. B. Walkom, Director, and Mr. H. O. Fletcher, Curator of Fossils, of the Australian Museum, Sydney, I was able to compare the Victorian incisor with material in that institution, where it was noted that *D. minor* is present in collections from N.S.W. localities. Dr. Walkom has now provided me with the following list of N.S.W. occurrences of *Diprotodon minor*:

Wellington Caves.
Weetalibah Creek, near Coolah.
Gunnedah.
Gilgoin Station, near Brewarrina.

Cobar.
Downside, near Wagga.
Greenbank, near Wandsworth.

The known localities of *D. minor* are plotted in Fig. 2, which shows that the species has only lived (as far as is known) in south-east Australia. The species could well have evolved in the N.S.W. area and then radiated to contiguous areas. When our Pleistocene deposits have been subdivided and dated, it will be possible to trace the dispersal centre by its antiquity. Of the sites from which *D. minor* is known, the only one dated is the Victorian one, which is of the order of 12,000 years old (Gill 1953a).

FIG. 2.—Localities where *Diprotodon minor* has been found in Australia.

Problem of Extinction

Many reasons have been advanced for the extinction of Pleistocene marsupials. One is that they became too specialized in size. Thus *Diprotodon optatum*, the biggest marsupial that ever lived, is envisaged as becoming too large a mass of protein to be economically supported. However, the comparatively small *D. minor* suffered the same fate at about the same time.

Another reason given is that the Pleistocene animals were adapted for heat conservation in order to survive the rigors of the Ice Age. However, half of the Ice Age consisted of interglacial periods warmer than the present. Also, some of these animals date back to the Tertiary when the climate was more or less tropical. The nototheres, close relatives of *Diprotodon*, date back to the Tertiary (Gill 1953b).

Yet another explanation of extinction is that the mid-Holocene Arid Period wiped them out, but, as already mentioned, there were longer periods of warm climate during the Pleistocene, namely, the Interglacials. Moreover, these animals had the power to migrate and could move with the moving climatic belts.

The coming of the dingo is the key to the problem, some aver, yet giant marsupials died out in Tasmania where there was no dingo. The aborigine gets a share of the blame, but although he must have exercised some control on the numbers of these animals, he could not be the sole cause of their extinction. Some forms became extinct before the aborigines reached Australia. Indeed, the problem of the extinction of *Diprotodon minor* and other numerous Australian marsupials is a problem not yet solved.

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11

PRELIMINARY REVISION OF THE FAMILIES PATELLIDAE AND ACMAEIDAE IN AUSTRALIA

By J. Hope Macpherson, M.Sc.

[Read 9 December 1954]

Introduction

Recent surveys of intertidal zonation in Australia have stressed the importance of certain groups of animals and plants as indicators both of littoral zones and as markers of biogeographical divisions. The desirability of obtaining constant conditions makes it necessary to carry out such surveys on areas of extreme exposure. Hence the animals and plants found are confined to those that can retain their hold on the rocks, even in the fiercest gales. The two families reviewed in the present paper have this ability and most of their members are very selective in confining their position to a limited vertical area (zone) within the tidal range.

Map I

The division of coastal areas into climatic "Regions" by Stephenson (1948) is a primary one of more universal application than the "zoological provinces" earlier established for Australia by Hedley and others. References to Map I will make it clear that the Tropical Region of Australia is composed of more than one zoological complex, the eastern Solandrian and the western Dampierian Provinces of Hedley. It has been considered necessary to include this biogeographical map so that the smaller distribution maps of species may be orientated.

The biogeographical range of the various species differs considerably but with one doubtful exception no species is found both in the temperate and tropical regions. Other species are confined to the warm temperate or the cool temperate, and for some reason yet to be explained some occur only in the Flindersian province of the warm temperate, although some faunal elements of this and the Peronian province do meet in Victoria.

Ecological work has been carried on simultaneously in Western Australia and Victoria (Bennett and Pope, 1953) and more recently in Queensland; New South Wales was worked in 1946 (Dakin, Bennett and Pope, 1948). Molluscs, and particularly limpets, were sent to the National Museum for identification by various workers, and it soon became clear that species, genera and, even in one case, a family have been wrongly identified in the past. Probably this was in part due to the sparse material available to earlier workers. It is obvious that the intense, carefully documented collecting necessary for an ecological survey would reveal new forms and show new localities for known species.

There are necessarily many gaps in the present paper because there are still large areas that are unworked, and some of those that have been broadly surveyed still require more intensive collecting. The whole of Northern Australia and North-Western Australia is untouched. Kangaroo Island, South Australia, is the only part of that State which has been intensely worked; Tasmania is also untouched.

It soon became apparent that identification of limpet species by shell characters alone was a difficult task. Therefore, the author sought other characters which would be constant within a species but specifically different. W. R. B. Oliver (Oliver 1926) gave a lead by using the radula in conjunction with shell characters to define both genera and species. The present work has shown that, with the more extensive material available, radula characters can be used not only for specific determination, but also in separation of true subspecies. Oliver's simple definition of radula components has been used here.

In the families under consideration the radula is composed of recurring sets of teeth arranged on a long basement membrane. In each set there is usually an anterior element of several teeth close together in the middle line (centrals), a posterior element of two or more teeth not meeting in the middle line (laterals) and in some genera one or more small colourless and probably functionless teeth on each margin (marginals).

In these families the number of teeth in the various elements shows constant differences as follows:

Family Patellidae

Centrals. Typically with five, of which the centre tooth may be small or absent. In *Cellana* there are only two.

Laterals. A single pair, each carrying four cusps. *Cellana* has only two cusps.

Marginals. Three pairs, the outer two of which may be very small.

Generalized Radula formula. $3 \rightarrow 1\ (4) \rightarrow (2 \rightarrow 1 \leftarrow 2) \leftarrow 1\ (4) \leftarrow 3.$

Basement membrane. Not segmented except in *Cellana,* in which it shows partial segmentation.

Note: *Cellana* is obviously intermediate in radula characters and suggests that further study including anatomical dissection might prove it to be the stock of *Patellidae* from which *Acmaeidae* sprang.

Family Acmaeidae

Centrals. Always two.

Laterals. Always two pairs.

Marginals. Typically two pairs, but sometimes absent.

Generalized Radula formula. $2 \rightarrow 2 \rightarrow 2 \leftarrow 2 \leftarrow 2$.

Basement membrane. Segmented, each segment carrying a complete set of centrals, laterals and marginals.

In the compilation of this paper it is considered that photographs are much truer and more convincing than drawings and therefore photographs of each species discussed have been included. Radulas are exceedingly difficult to photograph, but I believe that the photographs show the characters claimed in the text. The slightly exaggerated text figure for each species is merely a simplified tracing from the relevant photograph.

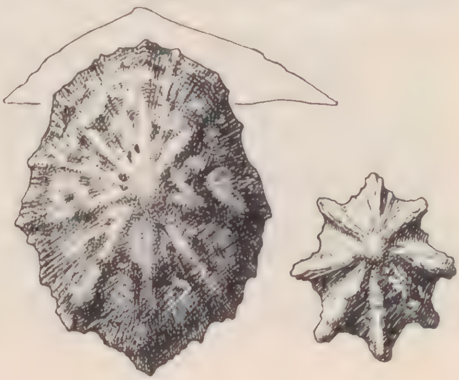
The symbols on the maps indicate records of each species as follows:

† = National Museum Collection.

* = In the literature.

Patellanax chapmani (T. Woods) (Pl. VIII, figs. 1 and 2)

Patella chapmani T. Woods, *Proc. Roy. Soc. Tas.,* 1875, p. 157.
Patella octoradiata Hutton (non Gmelin), *Cat. Marine Moll. New Zealand,* 1873, p. 44, No. 201, Pl. 1, Figs. 1-2.
Acmea alba T. Woods, *Proc. Roy. Soc. Tas.,* 1876, p. 155, No. 73.
Acmea sacharina perplexa Pilsbry, *Man. Conch.,* Vol. XIII, 1891, p. 50, Pl. XXXVI, Figs. 69, 71.
Acmea alba Pilsbry, *Man. Conch.,* Vol. XIII, 1891, p. 54, Pl. 42, Figs. 76, 7 and 8.
Patella perplexa Pritchard and Gatliff, *Proc. Roy. Soc. Vic.,* 15, 1903, p. 194.
Acmea octoradiata Hedley, *Proc. Linn. Soc. N.S.W.,* Vol. XXIX, 1904, p. 188; Pritchard and Gatliff, *Proc. Roy. Soc. Vic.,* 18, 1905, p. 65; Verco, *Trans. Roy. Soc. S. Aust.,* Vol. XXX, 1906, p. 209; Chapman, *Proc. Roy. Soc. Vic.,* 25, 1912, p. 186, Pl. XII, Figs. 1 and 2; Suter, *Man. N.Z. Moll.,* 1913, p. 75, Pl. VII, Fig. 6.
Patelloida perplexa Iredale, *Trans. N.Z. Instit.,* Vol. XLVII, 1915, p. 430.
Patella perplexa Peile, *Proc. Mal. Soc. Lond.,* Vol. 15, 1922, p. 16-17, Fig. 4.
Patelloida perplexa Chapman and Gabriel, *Proc. Roy. Soc. Vic.,* 36, 1923, p. 25.
Patella perplexa Iredale, *Proc. Linn. Soc. N.S.W.,* Vol. 49, 1924, p. 238.
Scutellastra chapmani Oliver, *N.Z. Journ. Science and Technology,* Vol. VII, 1924, p. 244.



Shell ovate, somewhat broad behind; apex acute, slightly to the anterior; eight more or less prominent radiating ribs, three anterior and five posterior. Whole shell sculptured with numerous fine radiating lirae which may be interrupted by encircling lines of growth; both ribs and lirae nodulose. Exterior of shell white, scorched with reddish horn flecks, interior white or tinted with pale rose; spatula scracely visible. In young thin shells the exterior colour may show to the interior.

Average dimensions. Length—20 mm. Width—16 mm. Height—6 mm.

The synonymy of this species shows that it was originally described from New Zealand by a New Zealand conchologist, Colonel Hutton. This description and record was based on shells in the Dominion Museum which have since been shown to be incorrectly labelled (Oliver 1924). Tennison Woods, *loc. cit.*, gave a very adequate and unmistakable description of the species. In 1876 he mistook the extreme form with almost even ribs for another species and described it as *Acmea alba.* Iredale (1924) has given a summary of the wide shell variation in this species and has shown that the degree of development of the ribs is due to environment.

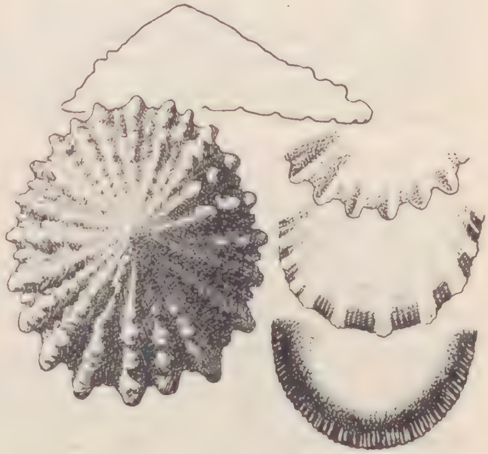
Radula (Pl. VIII, figs. 1 and 2). Both Peile and Oliver give diagrammatic figures of the radula but did not compare it with other members of the genus. The formula is $3 \rightarrow 1 \rightarrow (2 \rightarrow 1 \leftarrow 2) \leftarrow 1 \leftarrow 3$. In this species the median central is very small, flanked by two normal sized teeth. The large single lateral is 4-cusped; the innermost cusp is very small, the third is the largest. There are three typical colourless marginals.

Habitat. This shell is found in the lower littoral zone, living among the algae on the upper surface of rock platforms and boulders. This is a zone of dense algae growth which include the corallines, and the shells of this limpet are often encrusted with the latter and are difficult to see. It is a member of the ocean coastal fauna of New South Wales, Victoria, Tasmania, South Australia and southern Western Australia, including the Recherche Archipelago, but is absent from areas of maximum exposure.

Patellanax peroni (Blainville) (Pl. VIII, fig. 3)

Patella peroni Blainville, *Dict. Sci. Nat.* (Levrault), 38, 1825, p. 111.
Patella diemensis Philippi, *Zeitsch. fur Malak,* 5, 1848, p. 162.
Patella ustulata Reeve, *Conch. Icon.,* Vol. VIII, 1855, Pl. 31, Fig. 88 a, b.
Patella aculeata Reeve (non Gmelin), *ibid.,* Pl. 32, Fig. 90.
Patella squamifera Reeve, *ibid.,* Pl. 32, Fig. 94.
Patella tasmanica T. Woods, *Proc. Roy. Soc. Tas.,* 1876, p. 157.
Patella (Scutellastra) aculeata Pilsbry, *Man. Conch.,* Vol. XIII, 1891, p. 100, Pl. 25, Figs. 20, 21, and Pl. 62, Figs. 71-73.
Patella (Scutellastra) ustulata Pilsbry, *ibid.,* p. 101, Pl. 22, Figs. 11-12.
Patella hepatica Verco (non Pritchard and Gatliff), *Trans. Roy. Soc. S. Aust.,* Vol. 30, 1906, p. 207.
Patellanax squamifera Iredale, *Proc. Linn. Soc. N.S.W.,* Vol. 49, 1924, p. 239.
Patellanax squamifera Theile, *Handl. der Syst. Weightierkundle* Band I, 1931, p. 40.

Shell thick, oval, conical; apex slightly anterior; approximately 24 strong radiating, sub-carinate, rugose ribs, which increase in number with age; interspaces with radiating lirae. Margin irregular due to the projecting ribs making a sharply scalloped edge. Ribs white with interspaces yellow, brown or black. Interior porcellaneous, white, with a faint yellow or brown spatula; margin thin, crenulated, matching the exterior ribbing and colouration.

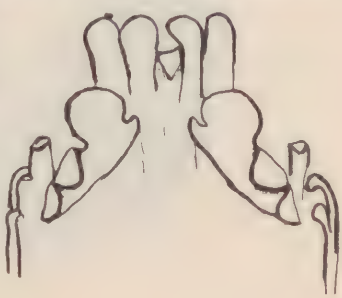


Average dimensions. Length—35 mm. Width—28 mm. Height—15 mm.

Patellanax aquamifera Reeve and *Patellanax hepatica* Verco have been placed in the above synonomy. It is evident that this species is very variable; colour and sculpture of shells from any one locality may differ considerably. At one end is the *squamifera* type with 24 large white ribs interspaced with smaller yellow ones. At the other end is the *peroni* type in which the numerous, almost uniform radials are dark with only an occasional light one.

There is also an extreme variant with uniform radials which are jet black in colour. This is Verco's *hepatica*, which both he and subsequent writers confused with the species now known to be *Patelloida victoriana* Singleton. (See note, p. 243).

The grading of a large series of shells from a single locality such as Lorne showed that all the above forms were present and that there were intermediates which made it impossible to separate them into distinct species. The evidence of the Lorne series was borne out in all other localities where a large series was collected, including localities in Western Australia and New South Wales.



Radula (Pl. VIII, fig 3). The radulas of shells from a number of localities were examined and they proved to be uniform in all details. As the remaining species of the genus can be separated on radula form, this evidence confirms the intergraduation of the shell characters.

Radula formula is $3 \rightarrow 1 \rightarrow (2 \rightarrow 1 \leftarrow 2) \leftarrow 1 \leftarrow 3$. The radula has five centrals, the median one small and possibly functionless. The single laterals bear four cusps, and on either side of these are three functionless marginals. The four cusps of the laterals vary in size; the inner one is very small, and is followed by a large rounded cusp and then two more diminishing in size towards the outer edge. All the teeth are dark brown with colourless bases, except for the marginals, which are entirely colourless. Claude M. Torr, *Trans. Roy. Soc. S. Aust.*, Vol. XXXVIII, 1914, p. 365, figures the radulas of *Patella ustulata* and *P. aculeata* and shows the former with only a single marginal tooth. Whether he had a malformed radula or failed to see the other transparent teeth it is impossible to say. If Dr. Torr's so-called *P. ustulata* is a true representation of the radula of his shell, then it would seem that he had a new species distinct from the present one.

Habitat. Very common on the exposed rock platforms of the lower littoral (Pyura) zone and descending to the sublittorial fringe among the hold-fast of the giant kelp *Sarcophycus potatorum* of New South Wales and Victoria. I have also examined specimens from Tasmania, South Australia and Western Australia, where it occurs in the corresponding algal zone.

Patellanax laticostata (Blainville) (Pl. VIII, fig. 4)

Patella laticostata Blainville, *Dict. Sci. Nat.* (Levrault), 38, 1825, p. 111.
Patella melanogramma Sowerby (non Gmelin), *Genera of Shells, Patella,* Vol. 1, 18, p. 140.
Patella neglecta Gray, *King's Intertropical Survey of Australia*, II, 1826, p. 156, 182, 492.
Patella rustica Menke, *Moll. Nov. Holl.*, 1843, p. 33; *Zeitsch. fur. Malak.*, 1844, p. 62.
Patella zebra Reeve (non Blainville), *Conch. Icon.*, VIII, 1854, Pl. 4, Fig. 7.
Patella (Scutellastra) neglecta Pilsbry, *Man. Conch.*, Vol. XIII, 1891, p. 95, Pl. 20, Figs. 41 and 2; Pl. 58, Figs. 40, 41.
Patella neglecta Gray, *Trans. Roy. Soc. S. Aust.*, Vol. XXXVI, 1912, p. 192.
Patella laticostata Iredale, *Proc. Linn. Soc. N.S.W.*, Vol. 49, 1924, p. 241.

Shell very thick, large, subconical, broader posteriorly; apex slightly anterior, strong, radiating, nodulose, subcarinate ribs, approximately 22 in young individuals but increasing in number with the growth of the shell, interspaces with fine striae. Ribs and striae white with brown interspaces, apex often eroded and white. Interior porcellaneous, white, with the spatula white or fused with red-brown; muscle impression well defined and often pale yellow in colour. Margin sharp, crenulated, matching the exterior ribbing and colouration.

Average dimensions. Length—90 mm. Width—60 mm. Height—30 mm. This species is the largest of the Australian limpets and its radula formula shows that it belongs to *Patellanax* and not *Cellana*, where it has been placed by some recent authors.

Radula (Pl. VIII, fig. 4). The radula formula is $3 \rightarrow 1 \rightarrow (2 \rightarrow 1 \leftarrow 2) \leftarrow 1 \leftarrow 3$. The radula is broad and the teeth are also wide and shovel-shaped. The median central is smaller than the other four. The large lateral has four cusps, the second from the inside being the largest; all the cusps are well defined. The three colourless marginals on each side are very distinct.

Habitat. Found in the zone of the lower littoral in western South Australia and southern Western Australia. The larger shells are often badly eroded, covered with algal growth and may have one or two specimens of *Patelloida nigrosulcata* attached to them.

Cellana solida (Blainville) (Pl. IX, figs. 1 and 2)

Patella solida Blainville *Dict. Sci. Nat.* (Levrault), Vol. 38, 1825, p. 110.
Patella rubraurantiaca Blainville, *ibid.*, p. 111.
Patella limbata Philippi (non Bolten), *Abbild. und Besch., Conch.*, Vol. III, 1849, p. 71, Pl. 3, Fig. 3.
Patella limbata Reeve, *Conch. Icon.*, Vol. VIII, 1854, Pl. 13, Fig. 29 a, b.
Helcioniscus limbata Pilsbry, *Man. Conch.*, Vol. XIII, 1891, p. 143, Pl. 71, Figs. 53-6, and Pl. 17, Figs. 28, 29.
Cellana limbata Hedley, *Journ. Roy. Soc. W. Aust.*, Vol. 1, 1914-15, p. 37.

Shell thick, very large, oval, conical, narrowing anteriorly, apex subcentral; approximately 26 strong, rounded, radiating ribs and distinct encircling growth lines. Colour is light grey or greyish pink with dark brown streaks in the interspaces between the ribs. Interior irridescent, grey in young shells, and yellow, pink or orange in adult shells, with the margin deeper in colour. The dark brown radial lines of the exterior often show through to the interior at the margin, and in young shells over the whole surface. Spatula grey or grey green with the muscle scar orange and very heavy in old shells.

Average dimensions. Length—78 mm. Width—65 mm. Height—34 mm.

As shown in the above synonymy, Blainville described this species twice, the two descriptions following each other in the text. The first description refers to the less eroded younger and smaller shells, which are always grey on the outside and lack the strongly orange red interior of older shells. The second description, as the name implies, refers to the older, very deeply coloured shells. Iredale (*Proc. Linn. Soc. N.S.W.*, 49, 1924, p. 241) states that the eastern Tasmanian shell is *solida* and is a different shell from the South Australian, which is *rubraurantiaca*. Comparison of the two series in the National Museum does not bear this out as the shells are indistinguishable. Examination of the radulas show that these also are the same, whereas all other radulas of the genus show specific differences.

Radula (Pl. IX, figs. 1 and 2). The radula formula is $3 \rightarrow 1\ (2) \rightarrow 2 \leftarrow 1\ (2) \leftarrow 3$. The typical very long coiled radula has long narrow teeth. The two centrals are simple single cusped teeth; the bicuspid laterals have one long sharp-pointed cusp with a minute secondary cusp nestled into its base, so that when broken off an indentation is left. The three marginals are simple; the inner one is much the larger of the three, with a distinct cutting edge on the turned apex. Dr. Torr (*Trans. Roy. Soc. S. Aust.*, 38, 1914, p. 365, Pl. XX, No. 11) gave a description and figures of the radula of *Helicioniscus limbata* Philippi which differs in a number of points from the present material. This gives no indication of Torr's third median central, and the small cusp of the bicuspid lateral, though very small, is elongated, wedge-shaped, with a distinct base joined to that of the larger cusps.

Habitat. Found in the algal zone of the lower littoral in eastern South Australia, Bass Strait islands, Glennies Group and Wilson's Promontory, Victoria and Tasmania.

Cellana tramoserica (Sowerby) (Pl. IX, figs. 3 and 4)

Patella tramoserica Sowerby, *Cat. Tankerville Coll.*, 1825, p. 30.
Patella variegata Blainville (non Gmelin), *Dict. Sci. Nat.* (Levrault), Vol. 38, 1825, p. 100.
Patella jacksoniensis Lesson, *Zool. "Coquille"*, Vol. II, 1830, p. 418.
Patella tramoserica Lamarck, *Anim. S. Vert.* (2nd ed., Desh), Vol. VII, 1836, p. 47.
Patella tramoserica Reeve, *Conch. Icon.*, Vol. VIII, p. 54, Pl. 13, Fig. 27a.
Patella variegata Reeve, *ibid.*, Pl. 16, Fig. 36a, b, c.
Helcioniscus tramoserica Pilsbry, *Man. Conch.*, Vol. XIII, 1891, p. 142, Pl. 70, Figs. 49, 52.
Helcioniscus melanostomus Pilsbry, *ibid.*, p. 151, Pl. 32, Figs. 67, 68, 69.
Cellana variegata Iredale, *Trans. New Zealand Instit.*, Vol. XLVII, 1914, p. 430.
Cellana tramoserica Iredale, *Rec. Aust. Mus.*, Vol. XIX, 1936, p. 289.
Cellana sontica Iredale, *Aust. Zool.*, Vol. IX, 1940, p. 433, Pl. XXXIII, Figs. 10, 11, 12.

Shell thick, large, conical, slightly broader posteriorly, apex subcentral; sculpture approximately 36 strong, subcarinate, radiating ribs, and numerous fine, closely set encircling growth lines; margin sharp, scalloped. The colour is very variable, and may be orange or pink, patterned with brown and white, or brown, patterned with yellow, orange and white; often every third or fourth rib is darker, giving a striped appearance, and in some the interspaces between the ribs are streaked with dark brown or black. Interior irridescent grey or yellow with the darker exterior colour showing through, particularly near the margin. Spatula white or grey.

Average dimensions. Length—53 mm. Width—45 mm. Height—28 mm.

This species, like many of our Australian limpets, has a long synonymy which has, for many years and by many authors, been recognized and therefore needs no comment. However, this does not apply in the case of *C. sontica* Iredale, a species erected for a shell from southern Queensland. A long series of *Cellana*, collected by Queensland University from the type locality of *sontica*, Caloundra, included specimens which corresponded in all details to the original description and figure of this species. This series showed a continual grading from the typical *C. sontica* to the typical *C. tramoserica*. I took the opportunity while in Sydney, in May 1953, to compare specimens of this series with Iredale's type of *sontica* and there is no doubt that they are identical. Because of the perfect grading between the two species, *C. sontica* must be added to the synonymy of *C. tramoserica*.

Radula (Pl. IX, Figs. 3 and 4). To confirm the evidence of shell characters, radulas of the two extreme forms were mounted and found to correspond in every detail. The radula formula is $3 \rightarrow 1\ (2) \rightarrow 2 \leftarrow 1\ (2) \leftarrow 3$. The two centrals are plain, single-cusped teeth. The laterals are bicusped, having the inner cusp as long as the centrals and with a notch approximately half way down it; the outer cusp is small and deltoid-shaped. There are three small single colourless marginals on either side, the inner one with a hooked edge being much the largest. These marginals are long narrow teeth extending the full length of each tooth block.

Habitat. On exposed rock surfaces in the mid-littoral zone but extending into both the lower and upper littoral zones of eastern South Australia, Victoria, New South Wales and southern Queensland. It is also recorded by May (Illustrated Index of Tasmania Shells, 1923) from the east coast of Tasmania.

Cellana conciliata Iredale (Pl. X, figs. 1 and 2)

Cellana conciliata Iredale, *Aust. Zool.,* Vol. IX, 1940, p. 432, Pl. XXXIII, Figs. 1, 2, 3, 19, 20.

Iredale, in his original description, described both the adult and young shell which he considers the common Cellana in north Queensland. His description is as follows:

"Shell broadly oval medium elevation, anterior slopes a little convex, posterior straight, apex at anterior third. The shell with age broadens out posteriorly without increasing elevation, and forms a large thickened shell all around the internal margin, while the tentacles leave a depression well marked on the shell. Sculpture of very numerous riblets, practically no concentric growth lines visible. Colouration, blue-green with indistinct darker radial bands; inside spatula of various shades of brown becoming paler with age; outside the spatula silvery blue, margin slightly marked with blue.

Length—40mm. Breadth—44 mm. Height—14 mm. Another 44 x 39 x 15. Type from Keppel Bay, collected by H. Bernhard.

The young shell is elongate oval, thin, transparent, not much elevated. Colouration alternate radial bands of pale greenish and blackish green, at first the pale bands dominant, but with age this is reversed, only narrow stripes of the paler colour being seen. The sculpture is more pronounced, sometimes the ribs showing a slight nodulation.

Length—21 mm. Breadth—15 mm. Height—7 mm. 18 x 14 x 6 mm."

The specimens used for detailed work on the radula were compared with the type specimen and correspond exactly. The shell shows certain constant differences from *tramoserica* and this is borne out in the radula.

Radula (Pl. X, figs. 1 and 2). Radula formula is $3 \rightarrow 1\,(2) \rightarrow 2 \leftarrow 1\,(2) \leftarrow 3$. The two centrals are long, plain cusps slightly longer than the bicuspid laterals. The long inner cusp of the lateral is notched at approximately one third from the point. The smaller delta-shaped outer cusp is about one third as tall as the inner one. Three short, stout, colourless marginals, the innermost being the largest. A projection on the basement membrane below each set of marginals gives the appearance of a second indistinctly defined group of marginals. The whole appearance of the teeth is shorter and slightly stouter than those of the radula of *C. tramoserica*.

Habitat. Found at low- to mid-tide level, its southernmost known range being Bargara, Queensland.

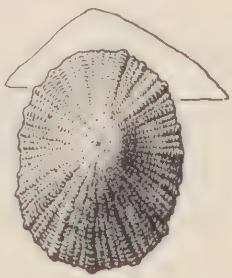
Cellana turbator Iredale (Pl. X, figs. 3 and 4)

Cellana turbator Iredale, *Aust. Zool.*, Vol. IX, 1940, p. 433, Pl. XXXII.

"Shell small, conical, rather regularly oval, elevated, apex at anterior third, eroded, anterior slope straight, posterior convex. Colouration greenish white with few black markings. Sculpture consists of coarse nodulose radials alternating larger and smaller, about twenty-five of each. Inside silvery white, the spatula brownish, no definite marginal markings.

Length—15 mm. Breadth—12 mm. Height—6 mm.

Type from Caloundra, South Queensland."



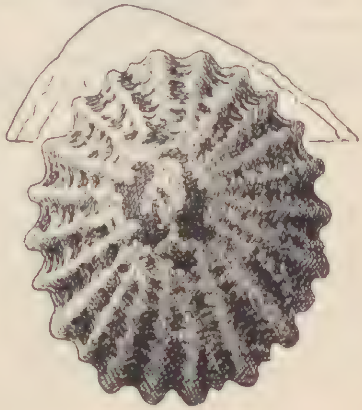
The present series collected by the Queensland University zoologist are from Caloundra and Cairns. The largest specimen of the present series is 26·5 mm. long by 20 mm. wide. With age the whole shell appears to darken and become overlain with steel grey inside and out. This has the effect of making the shell resemble *C. conciliata* or a dark *C. tramoserica*. It is distinguished from the former by the fawn instead of the yellowish white spatula, and stronger external sculpture, and from the latter by the strong alternately larger and smaller nodulose radials. The number of radials increases from between the older, more pronounced ones.

Radula (Pl. X, figs. 3-4). The radula is quite distinct from all the other species. Radula formula is 3 → 1 (2) → 2 ← 1 (2) ← 3. The two centrals are single-cusped except for a small spur on the outer edge of each tooth near the base. This spur is very clearly seen when the radula is looked at from above. The bicusped laterals have a long inner cusp, with a prominent notch about one-quarter of the way from the tip, and a deltoid cusp which is about a third the height of the inner cusp. The marginals are colourless; the outer one on each side is the largest and most clearly defined.

Habitat. Lower littoral, and frequently covered with Lithothamnian, Queensland.

Patelloida alticostata (Angas) (Pl. XI, figs. 1 and 2)

Patella alticostata Angas, *Proc. Zool. Soc. Lond.*, 1865, p. 56.
Patella costata Angas (non Sowerby), *Proc. Zool. Soc.*, 1867, p. 221.
Acmea costata T. Woods (non Sowerby), *Proc. Roy. Soc. Tas.*, 1876 (1877), p. 50; Pilsbry, *Man. Conch.*, Vol. XIII, 1891, p. 51; Pritchard and Gatliff, *Proc. Roy. Soc. Vic.*, Vol. 21, 1908, p. 382.
Acmea alticostata Hedley, *Proc. Linn. Soc. N.S.W.*, Vol. 29, 1904, p. 189; Verco, *Trans. Roy. Soc. S. Aust.*, Vol. 30, 1906, p. 209; *ibid.*, Vol. 36, 1912, p. 183, 197, Pl. 16, Figs. 3, 4; Iredale, *Proc. Zool. Soc.*, 1914, p. 670.
Patelloida alticostata Hedley, *Journ. Roy. Soc. W. Aust.*, Vol. 1, 1916, p. 35.
Patelloida alticostata antelia and *complanata* Iredale, *Proc. Linn. Soc. N.S.W.*, Vol. 49, 1924, p. 234.
Patelloida alticostata antelia Oliver, *Trans. N. Zeal. Instit.*, Vol. 56, 1926, p. 551.



Shell conical, solid; approximately 18 radiating ribs, subcarinate; apex slightly anterior and usually eroded; margin thin, scalloped. Colour white or grey-green due to algal growth which seems to attack this species very frequently.

Interspaces between the ribs marked with fine black cross-lines which are characteristic of this species. Interior porcellaneous, white, spatula grey and white, with the strong muscle scar tinged with brown. Margin light brown with the black of the exterior showing through on the indentations.

Average dimensions. Length—45 mm. Width—39 mm. Height—19 mm.

Radula (Pl. XI, figs. 1-2). The radula formula is $2 \rightarrow 2 \rightarrow 2 \leftarrow 2 \leftarrow 2$. The centrals are large with pointed spoon-shaped cusps and medium length bases. The inner laterals are very large, with rounded cusps; outer laterals are small, being about one-quarter the size of the inner pair. Bases are short. The marginals are well formed, with curving cusps. The radula segment is square. Radulas, like the shells of this species, are quite distinct and very uniform in appearance. Oliver, following Iredale's lead, separates eastern members of this species from those of southern and western Australia, remarking that the division is more dependent on geography than on anatomical characters. With this latter statement the present author concurs and therefore calls the whole series *alticostata.*

The creation of subspecies on a purely geographical basis is a dangerous practice, and it tends to mask the true boundaries of zoogeographical provinces. In ecological work species and subspecies must be clearly defined.

Habitat. Lives on exposed rock surfaces in the lower littoral. Shells are usually eroded and often partially covered with algal growth. Occurs from Geraldton, Western Australia, to southern Queensland and Tasmania.

Patelloida nigrosulcata (Reeve) (Reeve) (Pl. XI, figs. 3 and 4)

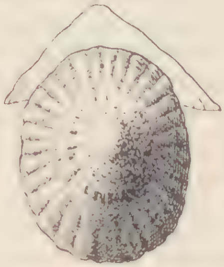
Patella nigrosulcata Reeve, *Conch. Icon.*, Vol. VIII, 1855, Pl. 30, Fig. 84.
Patella stellasformis var. *migrosulcata* Pilsbry, *Man. Conch.*, Vol. XIII, 1891, p. 100, Pl. 61, Figs. 66 and 67.
Acmea petallavecta Verco, *Trans. Roy. Soc. S. Aust.*, Vol. 36, 1912, p. 195, Pl. 15, Figs. 5-7; Pl. 16, Fig. 5.
Patelloida patellavecta Hedley, *Proc. Linn. Soc. N.S.W.*, Vol. 41, 1917, p. 708.

Shell ovate, rather solid, sharply conical, radially grooved, grooves narrow, distant; margin thin, faintly scalloped and conforming to the places of attachment; shell rough, chalk white, grooves more or less black; interior creamy-white, sometimes tinged with brown, spatula rimmed with brown, margin faintly lineated.

Average dimensions. Length—22 mm. Width—16 mm. Height—11 mm.

Verco thought this shell might be Reeve's species but described it as new under the name *Acmea patellavecta.* His description is very full and included a

description and diagrammatic figure of the radula. Verco's suspicion of the shell's identity was confirmed by Hedley, (1917), who quotes the following personal note which he had received from T. Iredale:



"Specimens of Verco's shell have been received at the British Museum and I compared them, with Mr. Edgar A. Smith's assistance; we agree that the identity is absolute."

Radula (Pl. XI, figs. 3 and 4). The radula formula is $2 \rightarrow 2 \rightarrow 2 \leftarrow 2 \leftarrow 2$. The centrals are broad spoon-shaped teeth with pointed cusps. The inner laterals are narrow, with rounded cusps, outer laterals very broad with a wide straight cutting edge. The marginals are wide, with turned-over cusps. All teeth have very short bases and the segments of the radula are twice as wide as long.

Habitat. Generally found attached to other shells such as *Patellanax laticostata*. Southern Western Australia and western South Australia.

Patelloida victoriana (Singleton) (Pl. XII, figs. 1 and 2)

Patella victoriana Singleton, *Proc. Roy. Soc. Vic.*, Vol. 49, 1937, p. 391, Pl. XXIII, Fig. 1, new name for *P. victoriaea* Gat. and Gab.
Patella hepatica Pritchard and Gatliff, *Proc. Roy. Soc. Vic.*, Vol. , 1903, p. 194; Verco, *Trans. Roy. Soc. S. Aust.*, Vol. XXX, 1906, p. 207; *ibid.*, Vol. XXXI, 1907, p. 99; Iredale, *Proc. Linn. Soc. N.S.W.*, Vol. 49, 1924, p. 240.
Patella victoriae Gatliff and Gabriel, *Proc. Roy. Soc. Vic.*, Vol. 34, 1922, p. 152, Pl. XXIII, Fig. 1.

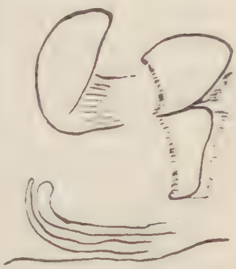
Singleton's description of this species is as follows:

"Shell elongate ovate, moderately elevated anterior slopes 47 deg., posterior slope 26 deg., nearly flat; sculptured by about 100 depressed subequal radiating riblets, increasing by division, crossed by fine lines of growth, interspaces almost linear. Apex subacute, slightly eroded, pointing anteriorly, situated in the anterior third of the shell. Colour dark brown, the interior white to bluish-white with brown margin. Length—23·7 mm., Breadth—18·9 mm., Height—8·5 mm."

This shell seems to have been a stumbling block to many conchologists. Pritchard and Gatliff referred our species to a Celebes shell with a pre-occupied name, *P. striata*, and Pilsbry erected *hepatica* in place of this name. Later in 1922 Gatliff and Gabriel decided that our shell was not the Celebes shell and erected a new name, *P. victoriae*, but still without description or figure, so their name is invalid.

Singleton finally renamed it in 1937 and gave a full description and figure. Probably the main reason for the difficulty over the name is that two species have been confused and different authors have in reality been discussing different shells. Verco (1906 and 1907) was apparently confusing the fine ribbed dark form of *Patellanax peroni* with this species, for it is unlikely that so careful a worker, with his well known interest in molluscan anatomy, would have overlooked the family characters of *Acmaeidae* which are present in *victoriana*. Verco stated that he considered *ustulata*, *aculeata* and *hepatica* to be conspecific. With this the present author concurs, if it be allowed that the shell Verco referred to as *hepatica* is not the present shell but the dark form of *Patellanax peroni*.

Gatliff, Gabriel and Singleton apparently based their work on shell material only and therefore failed to realize that they were dealing with an *Acmaeid*. However, the animal is typical of this family with a caudal gill plume and radula formula $2 \rightarrow 2 \rightarrow 2 \leftarrow 2 \leftarrow 2$. Also the shell is of the Acmaeid type as it has a dark spatula surrounded by lighter colour and an unbroken dark margin.

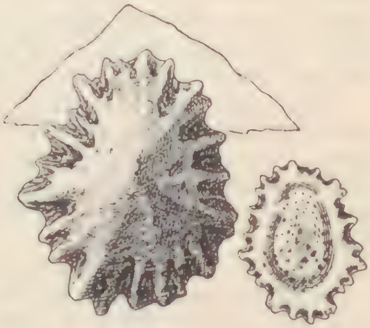


Radula (Pl. XII, figs. 1 and 2). The radula has stout, rounded cusped centrals, with the inner laterals approximately the same length. The outer laterals are smaller, with spoon-shaped cusps. The marginals are strong, with hook-shaped cusps. All the teeth have short bases and the segments of the radula are broader than long.

Habitat. In the sublittoral fringe on open rock platforms, amongst the holdfasts of *Sarcophycus potatorum*. This species is hardly ever taken alive because of the difficulty of reaching its habitat and because when eroded it can easily be mistaken for other species and is therefore not collected. Occurs in eastern South Australia, east Victoria to Wilson's Promontory, and Tasmania.

Patelloida saccharina stella (Lesson) (Pl. XII, figs. 3 and 4)

Patella stella Lesson, *Voy. "Coquille" Zool.*, Vol. 2, 1830, p. 421.
Patella stellaris Q. and Gaimard, *Voy. "Astrolobe" Zool.*, Vol. 3, 1834, p. 356, Pl. 71, Figs. 1-4.
Acmea saccharina stellaris Pilsbry, *Man. Conch.*, Vol. XIII, 1891, p. 50, Pl. 36, Figs. 63, 64, 67, 68.
Acmea saccharina Iredale, *Proc. Zool. Soc.*, 1914, p. 670.
Patelloida saccharina Hedley, *Journ. Roy. Soc. W. Aust.*, Vol. 1, 1916, p. 36.
Patelloida saccharina stella Oliver, *Trans. New Zeal. Instit.*, 56, 1926, p. 555.
Patelloida latistrigata Singleton, in part (non Angas), *Proc. Roy. Soc. Vic.*, Vol. 49, Pl. II, 1937, p. 390.



Shell ovate, subconical, thick, eight radiating ribs more prominent than the remainder, apex slightly anterior and usually eroded. Colour grey or white with interspaces between the ribs dark brown. Margin irregular star-shaped due to the projection of the eight ribs. Interior porcellaneous, grey or white, spatula white-dotted or blotched with brown; margin black with white stripes corresponding to the ribs.

Average dimensions. Length—25 mm. Width—20 mm. Height—8 mm.

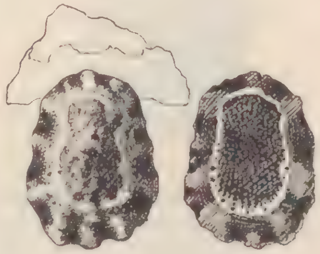
Radula (Pl. XII, figs. 3 and 4). The radula is stout and the segments almost square. The centrals have rounded cusps and medium length bases. The laterals have very short bases; the inner teeth are very stout with broad spoon-shaped cusps, the outer teeth are small. The marginals are long, narrow and curling.

A check of the material collected by the McCoy Society on Lady Julia Percy Island and described by Singleton (1937) showed that portion of the material he recorded as *Patelloida latistrigata* is in reality this species. This is a considerable extension of any previous recorded range and it will be interesting to note whether further collecting can locate it in the intervening areas or whether it is an outlier. It seems to be entirely absent from Victorian shores east of this point and is unrecorded from South Australia.

Habitat. Found on open rock platforms in the lower littoral zone, Northern Australia, Western Australia, northern New South Wales and Lady Julia Percy Island, Victoria.

Patelloida latistrigata latistrigata (Angas) Angas) (Pl. XIII, figs. 1 and 2)

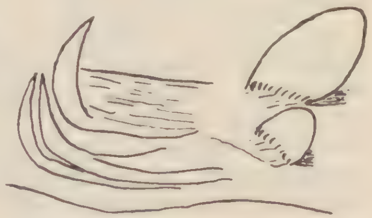
Patella latistrigata Angas, *Proc. Zool. Soc.*, 1865, p. 154.
Acmaea marmorata T. Woods, *Proc. Roy. Soc. Tas.*, 1875, p. 156; *ibid.*, 1876, p. 53.
Acmaea marmorata Pilsbry, *Man. Conch.*, Vol. 13, 1891, p. 52, Pl. 42, Figs. 66-68.
Helcioniscus latistrigata Pilsbry, *Man. Conch.*, Vol. 13, 1891, p. 143.
Acmaea marmorata Tate and May, *Proc. Linn. Soc. N.S.W.*, Vol. 26, 1901, p. 412.
Acmaea gealei Pritchard and Gatliff (non Angas), *Proc. Roy. Soc. Vic.*, Vol. 15, 1903, p. 198.
Acmaea marmorata Verco, *Trans. Roy. Soc. S. Aust.*, Vol. 30, 1906, p. 210; *ibid*, Vol. 36, 1912, p. 194.
Patella latistrigata Gatliff and Gabriel, *Proc. Roy. Soc. Vic.*, Vol. 21, 1908, p. 382.
Patelloida (Collesellina) latistrigata latistrigata Oliver, *Trans. N. Zeal. Instit.*, Vol. 56, 1926, p. 556.
Patelloida latistrigata Singleton, *Proc. Roy. Soc. Vic.*, Vol. 49, 1937, p. 390.



Shell conical, thick, approximately twelve radiating ribs, eight of which are more prominent; apex slightly anterior and usually very eroded; margin thin. Colour light grey, interspaces between ribs dark brown; when eroded the spatula colour often shows through as spots on the apex. Interior porcellaneous, grey-brown, margin striped with black corresponding to rib interspaces; spatula light brown, spotted or blotched with black, and bordered with white.

Average dimensions. Length—14 mm. Width—11 mm. Height—10 mm.

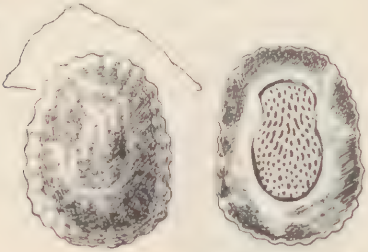
Radula (Pl. XIII, figs. 1 and 2). The radula formula is $2 \rightarrow 2 \rightarrow 2 \leftarrow 2 \leftarrow 2$. The centrals are medium sized, with very long bases. The outer laterals are both narrower and shorter than the rather broad inner pair. The long narrow recurved marginals almost meet behind the centrals. The segments of the radula are long and narrow.



Habitat. Exposed rock surfaces in the mid and upper littoral zone of South Australia, Victoria as far east as Wilson's Promontory, Bass Strait islands and Tasmania.

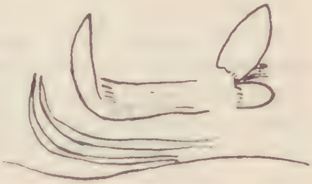
Patelloida latistrigata submarmorata (Pilsbry) (Pl. XIII, figs. 3 and 4)

Acmaea marmorata var. *submarmorata* Pilsbry, *Man. Conch.*, Vol. 13, 1891, p. 52, Pl. 42, Figs. 49, 70.
Patelloida submarmorata Iredale, *Proc. Linn. Soc. N.S.W.*, Vol. 49, 1924, p. 236.
Patelloida (Collisellina) latistrigata submarmorata Oliver, *Trans. N. Zeal. Instit.*, Vol. 56, 1926, p. 558.



This subspecies is smaller and flatter and the ribs are more numerous and uniform in size than those of *latistrigata* ss. The interior is grey, with the spatula spotted with dark brown and margined with white. Margin is thin and prickly.

Radula (Pl. XIII, figs. 3 and 4). The radula also shows some differences. All the teeth are longer and the bases of the centrals are slightly shorter, so that the segments of the radula are shorter than in *latistrigata*.



Habitat is similar to that of *latistrigata*. Occurs in southern Queensland, New South Wales and eastern Victoria (Mallacoota).

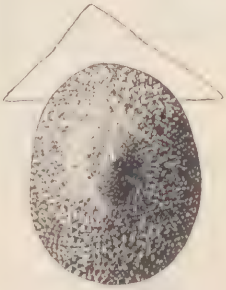
Chiazacmea flammae (Q. and G.)

This is a variable species with a wide distribution from southern Western Australia to southern Queensland. If the radula characters used by Oliver and the present author are a good basis for speciation, then one must recognize a number of distinct subspecies. These subspecies have slight but constant differences in shell pattern and shape of radula teeth, and separate geographical ranges. *C. flammae* is not an inhabitant of the open coast, but prefers the more sheltered waters of bays and inlets. This again has led to confusion, as another species, *Notoacmea granulosa* (see page), a shell of similar appearance from the ocean rock platform, has often been confused with it and occurs in many collections under its name.

Chiazacmea flammea flammea (Quoy and Gaimard) (Pl. XIV, figs. 1 and 2)

Patelloida flammea Quoy and Gaimard, *Voy. "Astrolabe" Zool.*, Vol. 3, 1834, p. 354.
Patella mixta Reeve, *Conch. Icon.*, Vol. VIII, 1855, Pl. 39, Fig. 129.
Acmaea flammea T. Woods, *Proc. Roy. Soc. Tas.*, 1876, p. 511; *ibid.*, 1877, p. 45.
Acmaea flammea Pilsbry, *Man. Conch.*, Vol. 13, 1891, p. 57, Pl. 37, Figs. 78-83; Pritchard and Gatliff, *Proc. Roy. Soc. Vic.*, Vol. 15, 1903, p. 196.
Acmaea cantharus Verco (non Reeve), *Trans. Roy. Soc. S. Aust.*, Vol. 30, 1906, p. 215.

Acmaea mixta Hedley (non Reeve), *Proc. Linn. Soc. N.S.W.*, Vol. 39, 1915, p. 713.
Chiazacmea flammea flammea Oliver, *Trans. N. Zeal. Instit.*, Vol. 56, 1926, p. 558.
Acmaea crucis T. Woods, *Proc. Roy. Soc. Tas.*, 1876, p. 52.
Acmaea jacksoniensis var. *mixta* Pilsbry, *Mann. Conch.*, Vol. 13, 1891, p. 58, Pl. 35, Figs. 32, 33.
Acmaea flammea Verco, *Proc. Roy. Soc. S. Aust.*, Vol. 36, 1912, p. 183.
Acmaea irradiata Hedley (non Reeve), *Proc. Linn. Soc. N.S.W.*, Vol. 39, 1915, p. 712.
Patelloida mixta Iredale, *Proc. Linn. Soc. N.S.W.*, Vol. 49, 1924, p. 234.



Shell oval, conical, elevated, apex slightly anterior, pointed; basic colour is cream overlaid with a network of fine brown lines and flamed with dark brown, often in the form of a Maltese cross. Interior grey, with the brown flames showing clearly, particularly at the margin; spatula brown in the centre with a light-coloured margin.

Average dimensions. Length—14 mm. Width—11 mm. Height—6 mm.

Radula (Pl. XIV, figs. 1 and 2). Radula formula is 2→2→2←2←2. The centrals have short bases and stout, long-pointed cusps. The inner laterals are as long as the centrals, with broad, rounded cusps. The outer laterals are very small and pointed. The marginals are long and narrow. The segments of the radula are slightly wider than long.

Habitat. On the upper surface of rocks in the lower littoral of sheltered bays and inlets, Tasmania, Victoria, eastern South Australia and southern New South Wales.

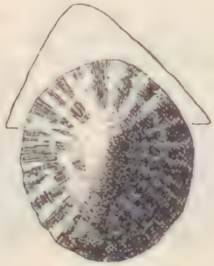
Chiazacmea flammea queenslandiae Oliver (Pl. XIV, figs. 3 and 4)

Chiazacmea flammea queenslandiae Oliver, *Trans. N. Zeal. Instit.*, Vol. 56, 1926, p. 561.
Patella jacksoniensis Reeve (non Lesson), *Conch. Icon.*, Vol. VIII, 1855, Pl. 39, Fig. 127.
Tectura jacksoniensis Angas (in part), *Proc. Zool. Soc.*, 1867, p. 220.
Acmaea jacksoniensis Pilsbry, *Mann. Conch.*, Vol. 13, 1891, p. 58, Pl. 42, Figs. 71-75.

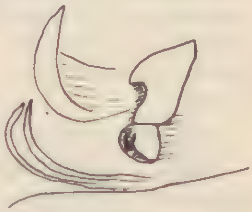
Shell conical, depressed, apex subcentral, slopes straight; plane of base arched, broadly elliptical. Outer surface smooth, often eroded, cream in colour, with 13 radiating brown bands, darkest at the margin and each consisting of several lines. Interior porcellaneous, white, with a few brown blotches, spatula light brown. Margin thin, showing the exterior bands.

Average dimensions. Length—14 mm. Width—11 mm. Height—5·5 mm.

Many specimens are higher than the type specimen, some being as much as 8 mm.



Radula (Pl. XIV, figs. 3 and 4). The radula form is typical of *flammae*, but the cusps of the inner laterals have the cutting edge more wedge-shaped than *flammea* ss. Oliver records only one subspecies of *C. flammea* from New South Wales, the small *mimula* Iredale, from the specialized *Crassostrea commercialis* association. However, the recent more intensive collecting has revealed a second form which is identical with *queenslandiae* Oliver.

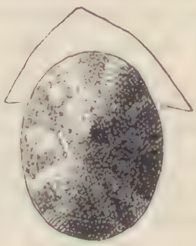


The subspecies is very common at Point Clare, Brisbane Water, Broken Bay, and is found attached to rocks along with *Syphonaria diemenensis* and *Crassostrea commercialis*. This is apparently a similar type of occurrence to the Queensland type habitat as recorded by Oliver, and confirmed by data with specimens recently collected by R. Kenny of Queensland University.

Habitat. Open rock surfaces, in sheltered bays and inlets of northern New South Wales and southern Queensland.

Chiazacmea flammea mimula (Iredale) (Pl. XV, figs. 1 and 2)

Notoacmea mixta minula Iredale, *Proc. Linn. Soc. N.S.W.*, Vol. 49, 1924, p. 235.
Chiazacmea flammea minula Oliver, *Trans. N. Zeal. Instit.*, Vol. 56, 1926, p. 561.



This subspecies is very close to *queenslandiae*, as pointed out by Oliver when he erected the latter, but it is retained in spite of the close association of the two forms in New South Wales because of its constant smaller size and higher elevation. The radula also shows slight differences in the shape of the radula segments, which are longer. The marginals have narrower curling cusps, and the inner laterals are more rounded.

Habitat. Intertidal, living on *Crassostrea commercialis* in New South Wales and recorded by Oliver from Tasmania (Blackman's Bay).

Chiazacmea heteromorpha Oliver (Pl. XV, figs. 3-4)

Chiazacmea heteromorpha Oliver, *Trans. N. Zeal. Instit.*, Vol. 56, 1926, p. 562, Pl. 99, fig. and text fig. C.

Oliver gives a very full description of this species and it is reproduced here.

"Shell elevated, conical, apex a little in advance of the centre, the sides convex, the anterior slope considerably steeper than the posterior, the surface rough, the apical portion eroded, but no ribs. Colour of uneroded portion dark brown. Margin irregular in outline, narrowed in front, and truncated anteriorly and posteriorly, the right side expanded behind the apex, the left side fairly regular. Plane of base irregular, evidently in adjustment to the rock-surface. Interior margin glossy, spatula porcellaneous. Spatula white with a brownish centre, margin jet-black, between these pale bluish-brown crossed by 6 broad black bands. Length 18 mm. Breadth 16 mm. Height 8 mm."

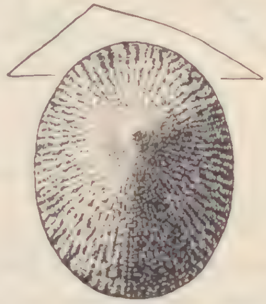
Range of variation. This species undergoes remarkable changes in its life-history. The young shell is perfectly regular in form, narrowed in front, apex in the anterior third, sides straight, finely ribbed, yellow with eight broad black rays. Spatula dark brown. As growth proceeds the margin expands irregularly in adjustment to the irregularities of the rock-surface, and the original regular young shell becomes the eroded apex of the adult. The colour-bands can be distinguished only in the marginal area of the inside, and occasionally on the outside. Generally the anterior three bands of the young shell, which are narrower than the others, are displaced by a simple broad band in the adult shell, thus giving six as the normal number of the adult. The spatula is sometimes obscurely rayed or spotted with brown. Half-grown shells clearly show the changing characters.

Radula (Pl. XV, figs. 3 and 4). Radula formula is 2→2→2←2←2. The centrals have pointed cusps and long bases. The inner laterals are large and broad and the outer ones very small. The marginals are very long, curling inwards above the centrals. The segments of the radula are slightly longer than broad.

Habitat. Upper surfaces of rocks from mid to lower littoral, Facing Island, Yeppoon, Bargara, Elliot River Head, Queensland; and shells only, which appear to be this species, from Cable Beach, Broome, Western Australia.

Chiazacmea cryptalirata sp. n. (Pl. XVI, figs. 1 and 2)

Shell conical, moderately elevated, thin, apex at anterior third, the sides convex, the anterior slope flattened and steeper than the posterior. The surface sculptured with faint broken ribs, which are masked by the colour pattern of red-brown flecks and stripes on a cream ground, overlaid with dark radiating stripes which may form a Maltese cross. Interior porcellaneous and light in colour except for the darker area of the spatula and the rays which can be clearly seen on the interior. The margin is thin.



Radula (Pl. XVI, figs. 1 and 2). Radula formula is 2 → 2 → 2 ← 2 ← 2. Centrals with pointed cusps. Inner laterals large, with triangular pointed cusps, outer laterals very small. Marginals broad, with turned-over cusps. All teeth have short bases and the radula segments are short and broad.

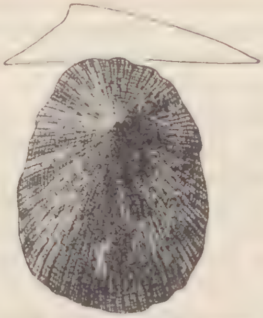
Dimensions of Type. Length—12 mm. Width—9·5 mm. Height—4 mm. Type in the National Museum of Victoria, Collection No. F.13856, Paratypes F.13861.

Habitat. On sheltered rock faces in littoral zone, Point Vernon, Yeppoon (type), and Dunwich, Queensland.

Chiazacmea ater sp. n. (Pl. XVI, figs. 3 and 4)

The description of the type collected by the Zoology School, University of Queensland, and located in the National Museum of Victoria, Collection No. F.13974, is as follows:

"Shell conical, moderately elevated, thin, apex less than a third from anterior margin, the sides convex, the anterior slope steeper than the posterior and slightly concave. The surface rayed with very fine but quite definite radiating ribs, which are much narrower than the interspaces, the width of which increases with distance



from the apex. Colour black; faintly mottled with brown and fawn. Margin thin, dark on the inside. Interior of shell grey-blue with a dark brown spatula."

Radula (Pl. XVI, figs. 3 and 4). Radula formula $2 \rightarrow 2 \rightarrow 2 \leftarrow 2 \leftarrow 2$. Centrals with narrow pointed cusps. Inner laterals broad, with V-shaped pointed cusps; outer laterals small. Marginals with distinct curling cusps. Bases of all teeth short, and radula segments slightly wider than long.

Dimensions of Type. Length—11 mm. Width—8·5 mm. Height—3·5 mm.

Habitat. On the under-surface of rocks in mid littoral Bargara (type), Yorkeys Knob, Cannonvale, and Flat Top Island, Queensland.

Notoacmea onychitis (Menke) (Pl. XVII, figs. 1 and 2)

Patella onychitis Menke, *Mulluscorum Novæ-Hollandiæ*, 1843, p. 34.
Patella onychitis Hedley, *Proc. Roy. Soc. W. Aust.*, 1, 1916, p. 36.

Shell conical, solid, ovate convex with 20 strong rounded radiating ribs, eight at anterior and close together and remainder evenly spaced; numerous fine encircling growth lines; apex subcentral; margin thin and crenulated. Blue-black between the ribs, flecked with cream, ribs cream, apical portion cream-flecked, with elongated brown marks. Interior porcellaneous, white, with a light brown spatula; margin striped with brown corresponding to the dark portions of the exterior.

Most shells of this species are very badly eroded and the typical exterior sculpture and colour pattern obliterated.

In eroded shells the apex is white with the remainder of the shell dark brown or black, more or less striped with white, depending on the depth of erosion. In such shells the margin is almost entire, but usually shows the dark bands on the interior.

Average dimensions. Length—19 mm. Width—16 mm. Height—10 mm.

Radula (Pl. XVII, figs. 1 and 2). The typical Notoacmid radula has centrals with stout pointed cusps and long bases. The inner laterals are shorter than the centrals, with rounded spoon-shaped cusps; the outer pair are shorter still, but as wide, with wedge-shaped cusps. The bases of the laterals are short. The radula segments are about one and a half times longer than wide.

Hedley listed this species in his West Australian list but without any comment beyond the original reference. It therefore seems probable that this species has not been recognized since Menke's description was written.

In 1950 Mrs. Loisette Marsh was working on the shore ecology of the Perth area and during the course of this work she collected a large series of patelliform gastropods, which she forwarded to the National Museum of Victoria for identification. This material included a large series of specimens of a species not immediately recognized by the author. Anatomical examination showed it to belong to the Acmaeidae and the radula formula $0 \rightarrow 2 \rightarrow 2 \leftarrow 2 \leftarrow 0$ placed it in the genus *Notoacmea*. No species of *Notoacmae* listed by Oliver or later authors correspond to this shell, but it was found that Menke's description of *Patella onychitis* fitted it very well, and so it is referred to that species.

Habitat. Mrs. Marsh's specimens from a number of localities are all listed as coming from the wave notch on vertical rock faces one to three feet above reef flat. South-western Western Australia.

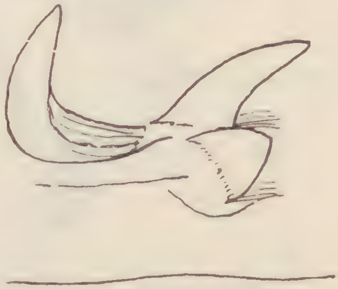
Notoacmea granulosa sp. n. (Pl. XVII, figs. 3 and 4)

This limpet, which is found in the upper littoral of exposed ocean platforms, has been confused with *Chiazacmea flammea* (or one of its subspecies) in most Victorian collections. The confusion has probably arisen because this species may carry a Maltese cross which is very similar to that of some forms of *C. flammea*. Examination of the radula, which is of the *Notoacmea* type and intermediate in form between *N. mayi* and *scabrilirata*, separates it from *Chiazacmea*. Also this is an inhabitant of the upper littoral of ocean coasts, whereas *Chiazacmea flammea* is only found in the quiet bays and inlets near low-tide mark. The description of the type from Warrnambool is as follows: Shell thick, conical, high apex slightly

anterior, anterior slope steep and almost straight; posterior slope convex, surface granulose, with faint radiating ribs. Colour grey, flecked with darker grey and brown; the flecks near the margin may be elongated into short stripes that show through to the inside. Spatula dark blue or brown, region between spatula and margin lighter in colour. Usually superimposed on the interior pattern is a bluish black Maltese cross which may show through to the exterior.

Dimensions of Type. Length—14·5 mm. Width—10 mm. Height—13 mm. Type in National Museum of Victoria, No. F.16131, Paratypes No. F.5834.

Radula (Pl. XVII, figs. 3 and 4). The radula has the Notoacmea formula, $0 \rightarrow 2 \rightarrow 2 \leftarrow 2 \leftarrow 0$. The centrals are stout and long with long bases. The inner laterals are nearly as long as the centrals and the outer half their length. All are spoon-shaped with rounded ends and short bases. The radula segment is longer than broad.



Habitat. Vertical surfaces of exposed rock faces in the upper littoral zone of ocean platforms, from Cape Bridgeway to Wilson's Promontory, Victoria, and Kangaroo Island, South Australia.

Notoacmea mayi May (Pl. XVIII, figs. 1 and 2)

Notoacmea mayi May, *Illust. Index Tasmanian Shells,* 1923, p. 100, Pl. 22, Fig. 33.
Acmaea cantharus T. Woods (non Reeve), *Proc. Roy. Soc. Tas.,* 1877, p. 45.
Notoacmea (*Notoacmea*) *mayi* Oliver, *Trans. N. Zeal. Instit.,* Vol. 56, 1926, p. 571.

Shell thick, domed, apex at anterior margin, anterior slope steep, posterior slope convex, surface faintly granulose. Colour grey-white, mottled with dark grey-brown. Interior black with a white or partially white spatula.

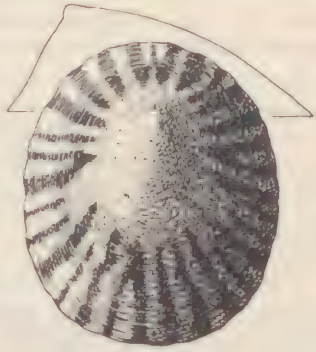
Average dimensions. Length—18 mm. Width—13 mm. Height—7 mm.

Radula (Pl. XVIII, figs. 1 and 2). The radula formula is $0 \rightarrow 2 \rightarrow 2 \leftarrow 2 \leftarrow 0$. Centrals medium length, stout, with pointed cusps and short bases. Laterals with short bases, the inner pair much longer than the small deltoid, outer cusps. Segments of radula longer than wide.

Habitat. On upper and vertical surfaces of ocean platforms in upper littoral in Tasmania, and Victoria, from Cape Bridgewater to The Nobbies, Phillip Island.

Notoacmea petterdi (T. Woods) (Pl. XVIII, figs. 3 and 4)

Acmaea petterdi T. Woods, *Proc. Roy. Soc. Tas.*, 1876, p. 155.
Tectura septiformis Angas (non Quoy and Gaimard), *Proc. Zool. Soc.*, 1867, p. 520.
Acmaea petterdi Pilsbry, *Man. Conch.*, Vol. 13, 1891, p. 54.
Notoacmea petterdi Iredale, *Proc. Linn. Soc. N.S.W.*, Vol. 49, 1924, p. 235.
Notoacmea (*Notoacmea*) *petterdi* Oliver, *Trans. N. Zeal. Instit.*, Vol. 56, 1926, p. 574.



Shell broadly elliptical, domed, posterior slope arched, anterior slightly convex, steep. Apex in anterior fourth. Ornamented with 28 fine radiating thread-like ribs extending from apex to margin, interspaces several times wider than the ribs. The whole with concentric growth lines. Colour cream, with about 40 light-brown radiating bands. Inside shining, dark; spatula brown, dark and light blotched; surrounding area bluish; margin thin, dark brown, outer edge banded with white.

Average dimensions. Length—20 mm. Width—16 mm. Height—7 mm.

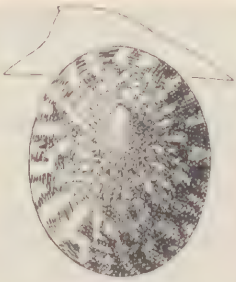
Radulas (Pl. XVIII, figs. 3 and 4). Radula segments are slightly longer than broad. The centrals are very long and pointed. The inner laterals are two-thirds the length of the centrals and the outer ones one-third smaller again and deltoid in shape. This is a very uniform species which is quite distinct, both in shell form and radula, from all other members of the genus.

Habitat. Usually found in colonies on the shaded side of vertical rock faces on ocean coasts. Upper littoral of north-west Tasmania, Victoria, New South Wales and southern Queensland.

Notoacmea septiformis scabrilirata (Angas) (Pl. XIX, figs. 1 and 2)

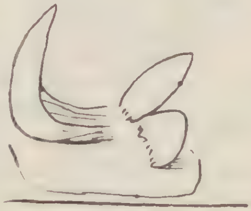
Acmaea scabrilirata Angas, *Proc. Zool. Soc.*, 1865, p. 154.
Tectura scabrilirata Angas, *Proc. Zool. Soc.*, 1867, p. 220.
Acmaea septiformis T. Woods, *Proc. Roy. Soc. Tas.*, 1876, p. 50.
Acmaea scabrilirata Pilsbry, *Man. Conch.*, Vol. 13, 1891, p. 56.
Acmaea septiformis Pritchard and Gatliff, *Proc. Roy. Soc. Vic.*, Vol. 15, 1903, p. 195; Verco, *Trans. Roy. Soc. S. Aust.*, Vol. 30, 1906, p. 215.
Notoacmea flammea Iredale (non Quoy and Gaimard), *Proc. Linn. Soc. N.S.W.*, Vol. 49, 1924, p. 235.
Notoacmea flammea diminuta Iredale, *Proc. Linn. Soc. N.S.W.*, Vol. 49, 1924, p. 235.
Notoacmea (*Notoacmea*) *septiformis scabrilirata* Oliver, *Trans. N. Zeal. Instit.*, Vol. 56, 1926, p. 573.

Shell thin, subconical; apex at anterior third; anterior slope concave, short, posterior convex; sculpture with many fine beaded radials, interspaces wider than ribs. Colour cream, overlaid with a reticulate or raised pattern of brown. Interior



white with the thin margin showing the exterior pattern, spatula cream or light brown.

Average dimensions. Length—14 mm. Width—10 mm. Height—4 mm.



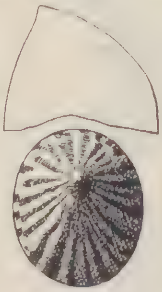
Radula (Pl. XIX, figs. 1 and 2). The radula has long centrals with short bases. The inner laterals are nearly as long as the centrals; the outer pair are shorter and deltoid in shape. The radula segment is square. Without a series of *N. septiformis* ss. it is impossible to judge the extent of the variation between the two subspecies, so until such time as we have a series it seems better to follow Oliver's division, although he himself seems in some doubt as to *scabrilirata's* validity.

Habitat. In colonies under stones, lower littoral of South Australia, Victoria, Tasmania, and New South Wales as far north as Sydney.

Notoacmea alta Oliver (Pl. XIX, figs. 3 and 4)

Notoacmea (*Conacmea*) *alta* Oliver, *Trans. N. Zeal. Instit.*, Vol. 56, 1926, p. 579, Pl. 99, Fig. 6.

Acmea conoides Pritchard and Gatliff (non Quoy and Gaimard), *Proc. Roy. Soc. Vic.*, Vol. 15, 1903, p. 195; Verco, *Trans. Roy. Soc. S. Aust.*, Vol. 30, 1906, p. 214.



Shell conical, elevated; apex subcentral, acute; anterior slope nearly straight, posterior slope regularly arched. Margin sharp; plane of base arched. Shell smooth, with concentric growth-lines. Black, with 18 pale green bands radiating from apex; colour-bands show on interior, which may be either light or dark brown, with an ill-defined spatula.

Average dimensions. Length—11 mm. Width—9 mm. Height—7 mm.

Radula (Pl. XIX, figs. 3 and 4). Radula has very short, broad teeth with short bases. The centrals have spoon-shaped cusps and the inner laterals are approximately the same length. Outer laterals are one-third as long, and deltoid in shape. The radula segments are wider than long.

Habitat. Living on the shells of *Brachyodontes rostratus* at mid littoral. Most shells are eroded and uniform grey-brown in colour. South Australia and Victoria.

Acknowledgements

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To Mr. Wallace Hastie, C.S.I.R.O. Forest Products, Mr. L. Bailleau, Melbourne Technical College, for photographing radulas; to Mr. G. J. Browning for the beautiful shell drawings.

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FIG. 1.—*Patellanax chapmani* T. Woods, to show marginals. × 150.

FIG. 2.—*Patellanax chapmani* T. Woods, to show four cusped laterals. × 150.

FIG. 3.—*Patellanax peroni* Blainv., × 150.

FIG. 4.—*Patellanax laticostata* Blainv., × 100.

FIG. 1.—*Cellana solida* Blainv., × 100. Side view to show centrals and laterals.

FIG. 2.—*Cellana solida* Blainv., × 100. Viewed from above to show marginals.

FIG. 3.—*Cellana tramoserica* Sowerby, × 100. Side view to show centrals and laterals.

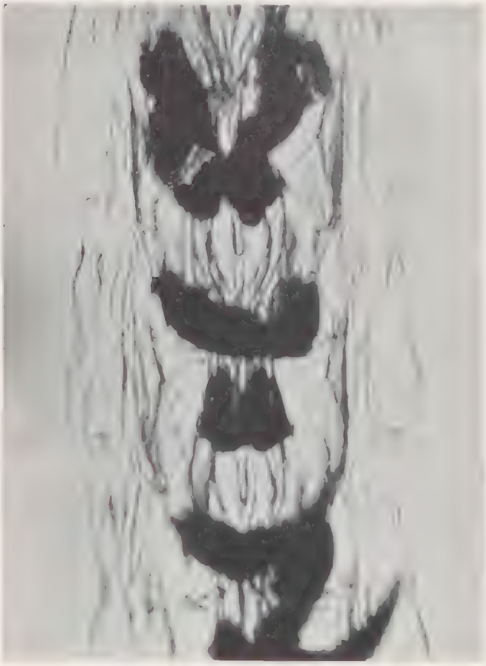

FIG. 4.—*Cellana tramoserica* Sowerby, × 100. Viewed from above to show marginals.

FIG. 1.—*Cellana conciliata* Iredale, × 150. Side view to show centrals and laterals.

FIG. 2.—*Cellana conciliata* Iredale, × 150. Viewed from above to show marginals.

FIG. 3.—*Cellana turbator* Iredale, × 150. Side view to show centrals and laterals.

FIG. 4.—*Cellana turbator* Iredale, × 150. Viewed from above to show marginals.

FIG. 1.—*Patelloida alticostata* Angas, × 150
Viewed from above.

FIG. 2.—*Patelloida alticostata* Angas, × 150.
Side view.

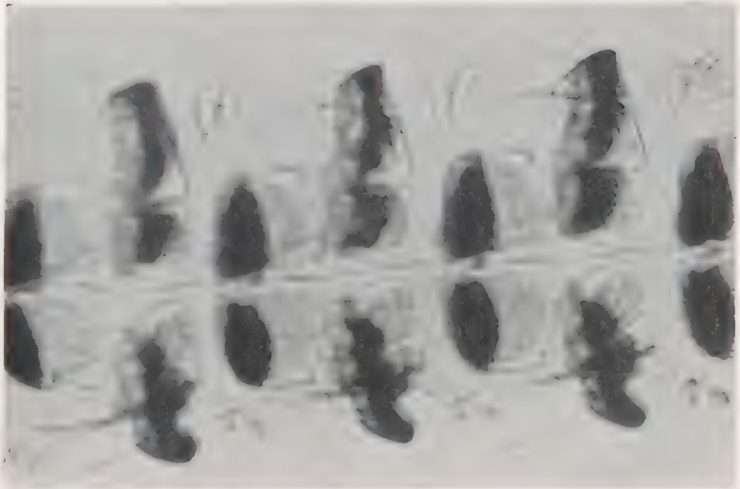

FIG. 3.—*Patelloida nigrosulcata* (Reeve), × 150.
Viewed from above.

FIG. 4.—*Patelloida nigrosulcata* (Reeve), × 150.
Side view.

FIG. 1.—*Patelloida victoriana* (Single), × 150.
Viewed from above.

FIG. 2.—*Patelloida victoriana* (Single), × 150.
Side view.

FIG. 3.—*Patelloida saccharina stella* Lesson, × 150.
Viewed from above.

FIG. 4.—*Patelloida saccharina stella* Lesson, × 150.
Side view.

FIG. 1.—*Patelloida latistrigata* (Angas), × 150. Viewed from above.

FIG. 2.—*Patelloida latistrigata* (Angas), × 150. Side view.

FIG. 3.—*Patelloida latistrigata submarmorata* (Pilsbry). × 150. Viewed from above.

FIG. 4.—*Patelloida latistrigata submarmorata* (Pilsbry). × 150. Side view.

FIG. 1.—*Chiazacmea flammea flammea* Quoy and G., × 150. Viewed from above.

FIG. 2.—*Chiazacmea flammea flammea* Quoy and G., × 150. Side view.

FIG. 3.—*Chiazacmea flammea queenslandiae* Oliver, × 150. Viewed from above.

FIG. 4.—*Chiazacmea flammea queenslandiae* Oliver, × 150. Side view.

FIG. 1.—*Chiazacmea flammea mimula* Iredale, × 150. Viewed from above.

FIG. 2.—*Chiazacmea flammea mimula* Iredale, × 150. Side view.

FIG. 3.—*Chiazacmea heteromorpha* Oliver, × 150. Viewed from above.

FIG. 4.—*Chiazacmea heteromorpha* Oliver, × 150. Side view.

FIG. 1.—*Chiazacmea cryptalirata* sp.n., × 150. Viewed from above.

FIG. 2.—*Chiazacmea cryptalirata* sp.n., × 150. Side view.

FIG. 3.—*Chiazacmea ater* sp.n., × 150. Viewed from above.

FIG. 4.—*Chiazacmea ater* sp.n., × 150. Side view.

FIG. 2.—*Notoacmea onychitis* Menke, × 150.
Side view.

FIG. 4.—*Notoacmea granulosa* sp.n., × 150.
Side view.

FIG. 1.—*Notoacmea onychitis* Menke, × 150.
Viewed from above.

FIG. 3.—*Notoacmea granulosa*, sp.n., × 150.
Viewed from above.

FIG. 1.—*Notoacmea mayi* May, × 150.
Viewed from above.

FIG. 2.—*Notoacmea mayi* May, × 150.
Side view.

FIG. 3.—*Notoacmea petterdi* T. Woods, × 150.
Viewed from above.

FIG. 4.—*Notoacmea petterdi* T. Woods, × 150.
Side view.

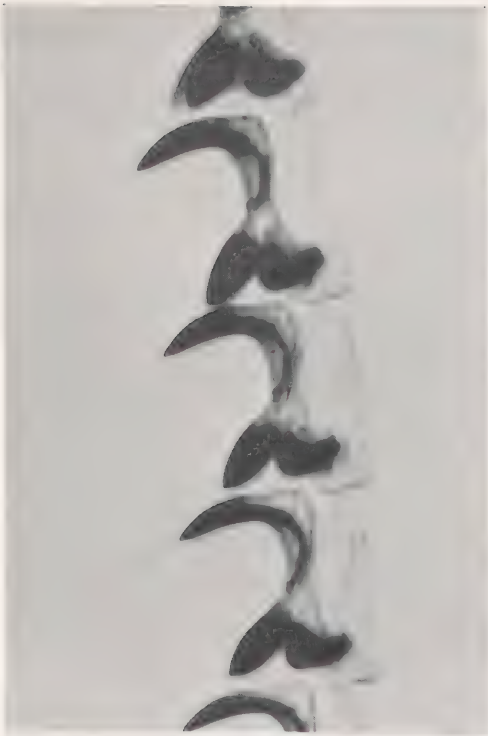

FIG. 2.—*Notoacmea septiformis scabrilirata* (Angas), × 150. Side view.

FIG. 4.—*Notoacmea alta* Oliver, × 150. Side view.

FIG. 1.—*Notoacmea septiformis scabrilirata* (Angas), × 150. Viewed from above.

FIG. 3.—*Notoacmea alta* Oliver, × 150. Viewed from above.

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INFLUENCE OF ENVIRONMENT AND VARIETY ON NITROGEN AND THIAMIN IN FIELD PEAS (*PISUM SATIVUM*)

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[Read 9 December 1954]

Abstract

Nitrogen and thiamin analyses of field peas (*Pisum sativum*) are presented. They include samples from the seasons 1941 to 1949 and from four States. Most of the detailed sampling comes from grain and haulm grown in the seasons 1945 to 1949 at Walpeup and Dookie, Victoria.

Environment affected nitrogen and thiamin levels through season and locality. Seed damaged by late rains in 1945 at Walpeup was much reduced in nitrogen and thiamin.

Differences in nitrogen level due to variety were highly significant. Insufficient varietal material was analysed for thiamin, but it seems likely that significant differences would result from larger sampling.

The variety Dun at Dookie showed a significant positive correlation of nitrogen and thiamin in the grain, whereas the variety Collegian at Walpeup showed no correlation. Dun also showed a slight positive correlation of thiamin and ash.

Nitrogen values of the dry haulm and pods without the seed were of the order of 1·2 to 3·8 per cent compared with wheat stubble 0·4 to 0·7 per cent.

Introduction

General

In Australia, recent emphasis on the supply of essentials for human and animal diets has stimulated fresh interest in legume crops as a source of protein and thiamin and also for their influence on soil fertility. In the period 1941 to 1943, Haughton and Coulter analysed the grain of *Pisum sativum* (field and vegetable varieties) and showed protein and thiamin levels at least twice as high as those of Australian wheats (Australian National Health and Medical Council, 1942). Further, this species is the most likely one to provide varieties of use in maintaining the soil fertility of those wheat areas of Victoria in which a pasture legume is not easily grown. Present commercial varieties yield too erratically in the drier parts of the wheat belt and so an attempt is being made to breed varieties for high yield of seed per acre. Clearly the maintenance and the increase in protein level of the crop is of importance.

In contrast to cereals, knowledge is lacking on the effect of environment and genotype on the quality of legume seed and haulm, and this is needed for better use of the present crop and for the breeding programme. Consequently data was gathered from analyses of various samples of peas grown at several localities in Victoria and elsewhere in Australia during the period 1941 to 1950. A few samples of haulm were included. This report gives some information on the factors controlling the level of protein and thiamin in the pea plant, particularly the seed.

Material

Apart from the samples obtained from commercial sources for the early analysis, material came from experimental plots concerned with varietal research on this crop. It was mostly from the Mallee Research Farm, Walpeup, and from the Agricultural College at Dookie. Walpeup has an average annual rainfall of 12·7

H

in.; in the years of sampling, 1945-49, it ranged from 10 in. to 15½ in. The soils are sandy. Dookie has an average rainfall of 21 in., with a range of 17-25 in. in the period 1945-49. The soils are clay loams.

The experimental plots from which the samples were selected for analyses included drilled plots of about a hundredth of an acre in size (1-2 bushel/acre in rate of seeding), and hand-sown plots, where seeds were sown about 3 in. apart in the rows. Spacing of seed along the row of the drilled plot was irregular, ranging from ½ in. to 12 in. Both drilled and hand-sown plots were sown in drills 7 in. apart, except for those varieties and crossbreds sown with wider spacing in observation rows. All sowings were made with superphosphate at a standard rate for the locality (Walpeup 90 lb./acre, Dookie 160 lb./acre). In the hand-sown plots, each plot was edged by wheat to divide each group and to reduce the border effect. All experimental plots from which samples were taken showed healthy growth. Good root nodulation was typical of the plant at both places.

Analyses

These resulted from the co-operation of a number of people. During the period 1941 to 1943, Joan M. Haughton, I. W. Robertson and J. Coulter analysed a number of varieties, and showed the existence of a wide range of values for protein and thiamin.

Over the period 1946 to 1952, the effect of variety and environment on protein and thiamin was followed in several series of samples. Through the co-operation of G. B. Jones of the Nutrition Laboratory, C.S.I.R.O., Adelaide, protein was estimated on over 200 samples of pea grain taken from the harvests of 1945 and 1946. Elizabeth Neville analysed for protein and thiamin 70 samples selected from the 1947, 1948 and 1949 harvests.

In 1952 and 1953, a number of samples, particularly of wheat and pea stubble from Walpeup, were estimated for protein by E. J. O'Brien of the Cereal Laboratory, Department of Agriculture, Victoria.

Protein was estimated from the nitrogen percentage using the factor 6·25. Other details of analytical methods are set out in Appendix I. The results of the grain analyses over the period 1941 to 1950 are summarized in Appendix II. As a matter of interest the range of these constituents in Australian wheats is added along with one set of figures on wheat in Canada. The haulm analyses are given later in the text.

The results were statistically analysed by R. Leslie, Betty Laby and Alison Doig of the Statistics Department, Melbourne University. Degree of significance is indicated by crosses (0·5, 0·1P, 0·01P being three to one cross respectively, or of high, medium and slight significance). It was recommended that further sampling on a field scale should be of the order of six to ten samples per treatment, because of the variation of result under field conditions.

Effect of Environment and Variety on Nitrogen and Thiamin of Grain

The analyses of samples from the harvests of 1945 to 1949 showed that season, locality and variety affected the nitrogen and thiamin levels.

Effect of Season at One Locality

Information on the effect of season is shown in Table 1 for Collegian at Walpeup, and in Table 2 for Dun at Dookie. At Walpeup, the effect of season is highly significant when the results for 1945 are included, and moderately significant when this year is omitted. The low value of both thiamin and nitrogen for the

grain for the 1945 harvest was associated with damaged grain with a "bubbly" appearance (see later section) and low variability. There was little difference in nitrogen level in the samples from the drilled plots in the years 1946 to 1949, but the thiamin levels showed larger differences, and the lowest level in 1949 was associated with higher rainfall in September than in the other two seasons. The pea varieties are in the podding stage at this time. Table 2 shows the figures for the variety Dun at Dookie arranged according to season. In the hand-sown plots there is no significant difference in nitrogen content in spite of the range in season, and only a slight difference in the thiamin level. In the drilled plots, the nitrogen results for 1949 are distinctly lower than in 1948. The thiamin shows the same trend but is not significantly different. In 1949 there was higher rainfall in Novem-

TABLE 1

Effect of Season on Variety Collegian at Walpeup

Season	HANDSOWN					DRILLED				
	Sample No.	Nitrogen		Thiamin		Sample No.	Nitrogen		Thiamin	
		%	S.E. Mean	Mcgm/gm	S.E. Mean		%	S.E. Mean	Mcgm/gm	S.E. Mean
1945*	4	2·66	0·08	4·39	0·30					
1946	2	4·00	0·71			2	4·05	0·11		
1947						4	3·53	0·08	7·89	0·30
1948						6	3·70	0·06	8·77	0·24
1949	4	3·76	0·08	8·94	0·30	7	3·98	0·08	7·13	0·30
Significance		xxx		xxx			x		xx	

* Seed damaged by rain before harvest.

TABLE 2

Effect of Season on Variety Dun at Dookie

Season	HANDSOWN					DRILLED				
	Sample No.	Nitrogen		Thiamin		Sample No.	Nitrogen		Thiamin	
		%	S.E. Mean	mcgm/gm	S.E. Mean		%	S.E. Mean	mcgm/gm	S.E. Mean
1945	3	3·62	0·09	7·69	0·34					
1946	4	3·96	0·08							
1947	2	3·62	0·11	9·36	0·42					
1948	3	3·79	0·09	9·84	0·34	8	3·58	0·06	8·91	0·21
1949	6	3·66	0·06	9·75	0·24	3	2·82	0·09	8·11	0·34
Significance		N.S.		x			xxx			

TABLE 3

Effect of Locality on Nitrogen and Thiamin in Grain of Pea Varieties

Year	Variety	WALPEUP					DOOKIE					Type Plot
		Sample No.	Nitrogen		Thiamin		Sample No.	Nitrogen		Thiamin		
			%	S.E. Mean	mcgm/gm	S.E. Mean		%	S.E. Mean	mcgm/gm	S.E. Mean	
1945	Collegian ..	10	2·63	0·05			3	3·79***	0·09			Handsown Plot
	White Brunswick	6	2·82	0·06			6	3·92***	0·06			,, ,,
	M.U. 33 ..	7	3·06	0·06			4	3·76***	0·08			,, ,,
1946	Collegian ..	2	4·00	0·11			4	4·06	0·08			,, ,,
	W. Brunswick ..	4	4·06	0·08			3	3·97	0·09			,, ,,
	,, ,, ..	4	4·58**	0·08			4	4·00	0·08			Handsown Row
	M.U. 225 ..	2	4·23**	0·11			5	3·75	0·07			Handsown Plot
	224 C ..	2	4·41**	0·11			5	3·75	0·07			,, ,,
	224 A ..	2	4·46**	0·11			4	3·74	0·08			,, ,,
	231 ..	4	4·21**	0·08			4	3·62	0·08			,, ,,
1947	Collegian ..	4	3·53	0·08	7·89	0·30	1	3·49		8·44		Drilled
1949	W. Brunswick ..	1	3·69		9·73		2	4·28	0·11	12·85	0·42	Handsown Plots
	Collegian ..	4	3·76	0·08	8·94	0·30	2	3·80	0·11	11·35**	0·42	,, ,,
	M.U. 33 ..	1	3·60		7·89		1	3·87		9·75		,, ,,
	Mammoth Blue	1	4·11		12·40		2	3·93	0·11	12·85	0·42	,, ,,
*Wheats—4 Varieties** ..												
1941	Bencubbin ..		2·6		5·6			1·5		4·6		
	Dundee ..		2·5		6·6			1·6		5·0		Drilled Plots
	Ranee		2·2		5·5			1·6		4·6		
	Ford		2·6		5·5			1·9		5·6		
1942	Bencubbin ..		2·1		5·2			1·3		4·9		
	Dundee ..		2·0		5·2			1·4		6·3		
	Ranee		1·8		5·2			1·5		4·2		
	Ford		2·0		5·3			1·5		5·8		

* Aust. National Health and Medical Research Council (1942).

ber than in other years and it included fairly heavy rain over three days towards the end of the month. It is likely that some damage to seed occurred in the rain-flattened drilled plots, while the small hand-sown plots were held erect by their boundaries of wheat.

In addition to the effect of season, small significant differences were found between nitrogen and thiamin levels of the same variety sown in hand-sown plots compared with drilled. These differences might result from fertilizer placement and suggest an investigation of the effect of nutrient supply on nitrogen and thiamin levels of the grain. Several workers (Langston 1951, Burkholder and McVeigh 1940, and Finch and Underwood 1951) have shown that such constituents of a cereal seed can be affected by the supply of nitrogen, phosphorus, sulphur and other elements to the root.

Effect of Locality

In Table 3, data is given for the same varieties grown at both Walpeup and Dookie in the same years. Figures for four wheat varieties are added for comparison (Australian National Medical and Research Council, 1942). It must be remembered that peas grown at Walpeup were manured at half the phosphate rate of those at Dookie.

Because of the shorter growing season at Walpeup the pea varieties grown there were predominantly of early maturity. Varieties of the mid-season type such as Dun, suited to the conditions at Dookie, only yield well at Walpeup in the exceptionally late season, and so rarely produced seed needed for these analyses. The New Zealand variety, Mammoth Blue, is the only one of such a type in Table 3. The number of samples of each variety is too low in some cases for statistical treatment, but general trends can be seen. The nitrogen figures show that results vary according to year. In 1945, three varieties are significantly higher at Dookie than at Walpeup because of the seed damage at the latter place. In 1946 five out of six varieties were higher at Walpeup than at Dookie. This same effect is to be noted in the wheat varieties for the two years quoted and has been found consistent for other years. However, for peas, further testing is needed to show if a similar increase of protein is usual at Walpeup compared with Dookie. Considering the thiamin figures, Collegian in 1949 was significantly higher at Dookie than at Walpeup. The three other varieties listed show the same trend.

Effect of Variety

Significant differences of nitrogen level due to variety were shown for some varieties and crossbreds in the seasons 1945 and 1946 at both Dookie and Walpeup. The results are listed in Table 4. As in wheat, the differences were often of the

TABLE 4

Effect of Variety on Nitrogen of Grain

Year	Place	Plot Type	Variety No.	Nitrogen Percentage Range of Means	Significance
1945	Walpeup	Handsown	6	2·6 — 3·1	xx
1945	Dookie	,,	6	3·5 — 3·9	xx
1945	,,	Broadcast	3	3·6 — 4·0	xxx
1946	Walpeup	Handsown	8	4·0 — 4·6	N.S.
1946	Dookie	,,	7	3·7 — 4·0	xx

same order as those due to season and to locality in the one variety. Varietal differences in thiamin level have not been adequately tested as yet, the only figures being those listed in Table 3.

Association of Thiamin with Nitrogen and with Ash

Interest was aroused in the possible association of thiamin with nitrogen and with ash in the pea grain through the report of such associations in cereals, especially wheat. Sufficient pea analyses were available only for Dun at Dookie and Collegian at Walpeup.

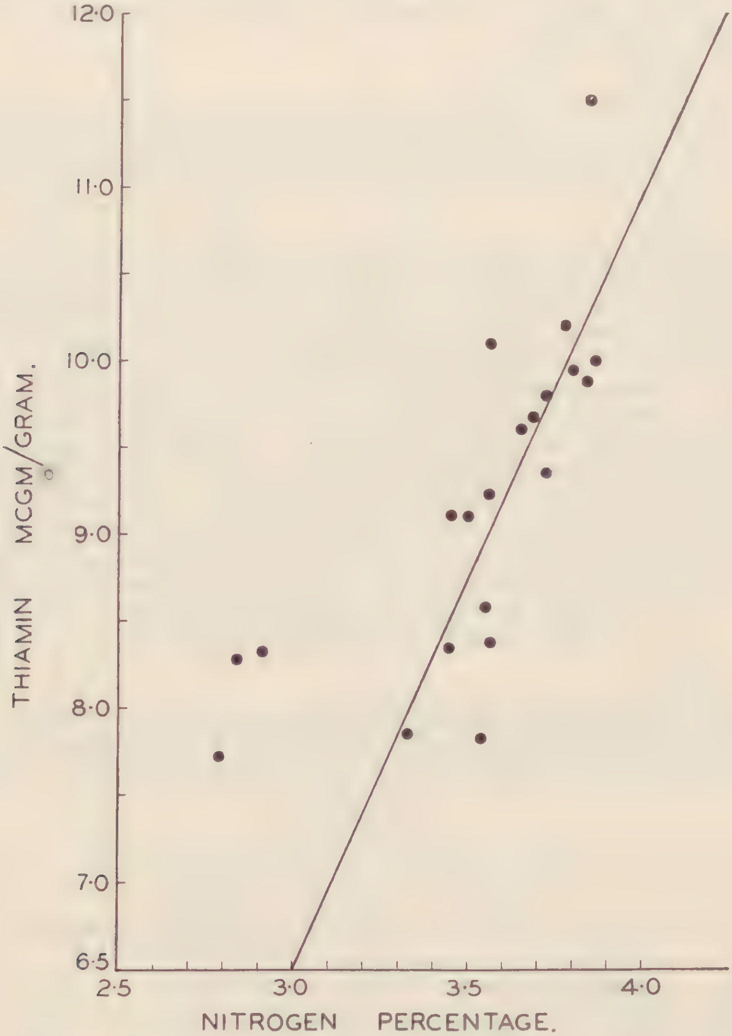

Fig. 1.—Nitrogen and thiamin in pea grain, variety Dun, at Dookie. Correlation, $r = +0{\cdot}79$.

Thiamin and Nitrogen

A highly significant correlation ($\tau = +0{\cdot}73$) of thiamin with nitrogen was found for the variety Dun at Dookie for the years 1947 to 1949, but only a low correlation ($\tau = +0{\cdot}33$) for Collegian at Walpeup. Figure 1 shows the scatter diagram for Dun at Dookie. The three values in the bottom left-hand corner are from the 1949 drilled plots, and therefore from samples that included damaged seed. If these values are left out, the correlation is higher still ($\tau = +0.79$).

Thiamin and Ash

The values for Dun at Dookie showed a correlation of $\tau = +0{\cdot}42$ (0·01P), while those for Collegian at Walpeup had a correlation of $\tau = +0{\cdot}20$ (not significant).

Distribution of Nitrogen and Thiamin in Grain and in Haulm

For certain uses of the pea crop, knowledge is needed not only of the value of the whole grain, but also of the distribution in the grain of nitrogen and thiamin. In addition, the nitrogen and fibre in the rest of the plant needs study if its value for grazing purposes is to be assessed. Some information on these points has resulted from local research in 1941-42, and from recent analyses.

Normal Grain

Figures concerning the distribution of nitrogen and thiamin within the grain are given in Table 5. Joan M. Haughton (1942) separated the seedcoat from the cotyledons and embryos of samples of two commercial varieties of field pea, Dun and White Brunswick. The seedcoats contained little nitrogen. However, samples of pea pollard and split peas produced commercially by crushing bulk supplies proved both to be similar in nitrogen level to the whole grain. The pea pollard is made up of seedcoat and of the outer edges of the cotyledons rubbed off in the

TABLE 5

Distribution of Nitrogen and Thiamin in Grain of Pea and Wheat

Analyst	Variety	Sample Type	Nitrogen %	Thiamin mcgm/gm
	Peas			
Haughton	Dun	Cotyledon	4·0	8·5, 11·1
		Testa	0·6	—
		Pollard	4·8	7·5
		Split Peas	4·5	10·3
Coulter	Tasmanian Blue	Embryo		11·2
		Cotyledon		7·9
		Outside layer of cotyledon		8·8
		Testa		0
	Wheat			
O'Brien+		Pollard	2·1	13·2
Clare & Underwood*		Grain	1·5	3·7

+ O'Brien: Nitrogen analyses F.A.Q. Victorian Wheat, mean 8 years, 1944/45 to 1953/54.
* Clare & Underwood: Thiamin analyses W.A. wheat from 4 mills 1947.

crushing process. As the seedcoats are so low in nitrogen, it is presumed that the outside layers of the pea cotyledon are somewhat higher in nitrogen than the inner layers, to result in the level of the pea pollard being equivalent to that of the split peas. Contrasting with wheat, there is no localization of protein granules in the outer layers of the cotyledon and therefore no great superiority of nitrogen level in the pollard compared with the rest of the grain.

Thiamin estimates done by J. Coulter (1943) showed that for the varieties Dun and Tasmanian Blue there was a higher level of thiamin in the tissue of the embryo than in that of the cotyledons. Scrapings of the outside layers of the cotyledons showed a slightly higher level there also. The testa had none. Commercial samples of pea pollard and split peas derived from Dun variety showed a lower value of thiamin in the Pollard compared with that in the split peas. Wheat pollard, on the other hand, was much higher than the whole grain. This points to a more even distribution of thiamin in the pea grain than in the wheat.

"Bubbly" Grain

The damaged grain from the 1945 harvest at Walpeup showed localized swellings of the seedcoat and, below these, circular white areas extending into the tissue of the cotyledon. Microscopically, the white areas differed from the normal tissue in the separation of many of the cells from each other and in the presence of free starch grains. Appropriate staining showed no sign of bacterial cells or fungal hyphae. The floury white material from these areas was extracted by means of a drill in sufficient quantity for estimation of nitrogen. This was compared with that from non-damaged areas. One sample was taken from typically damaged seeds of one variety from the hand-sown plots at Walpeup, all of the varieties tested being affected badly. The other samples were from a single plant from the F2 crossbreds at Dookie, where such damage was occasional. Table 6 shows that the

TABLE 6

Nitrogen Content of Grain, Season 1945

Locality	Sample Type	Nitrogen %
Dookie	"Bubbly" seed	3·2
	Normal	4·0
Walpeup	Floury patches in cotyledon of "bubbly" seed	2·0
	Normal sections of cotyledon of "bubbly" seed	3·9

nitrogen percentage was distinctly lower in the damaged tissue of the damaged seed. In Table 1 it can be seen that the thiamin content of damaged seed at Walpeup was well below that of the range for the other seasons, and the order of reduction was even more than that for the nitrogen. It seems reasonable to conclude that the reduction was from the same cause. Examination of the weather records for that season showed that the only unusual feature was several consecutive days of rain towards the end of the maturing stage of the crop. Table 7 shows the occurrences of a prolonged rainy spell late in October and those of damaged ("bubbly") seed over the seasons 1939 to 1952. Pea plots sown from May to June are ready for harvesting by the first week in November, or slightly before this. Rain during October may be too late to benefit the crop, and even makes possible fungal attack on the dying or dead tissue of leaf and stem and pod,

TABLE 7

Relation of Rainy Weather (October) to Bubbly Seed, Walpeup, 1945 to 1952

Season	Incidence Rain on Three or More Consecutive Days			Pea Grain
	No. days	Date	Amount (Pts)	
1945	5	26–30/10	130	Most seeds bubbly
1947	5, 3	1–5/10; 20–22/10	60; 70	Normal
1948	4	11–14/10	160	Normal
1949	5, 5, 4	2–6/10; 12–16/10; 23–26/10	80, 56, 90	Some bubbly seed
1951	4	22–25/10	40	Normal
1952	3	25–27/10	80	Some bubbly seed

and damage to the maturing or mature seed inside the pod. The damage to the seed described above as "bubbly" has not been produced experimentally so far, so that it is not yet known whether wetting and drying the mature pod several times before the seeds are dry, or just afterwards, is the necessary condition for the damage. The appearance is similar to "mottled" grain in wheat, a condition greatly influenced by environment, particularly by the rate of drying-out of the grain before harvest (Raw, 1932).

Seed damaged to the drastic extent of that from the 1945 harvest has not occurred again in the period 1939 to 1952, therefore this damage is regarded as

TABLE 8

Nitrogen and Fibre Percentages of Pea and Wheat Haulm

Analyst	Variety	Place	Type	Sample No.	Nitrogen		Fibre	
					Mean	Range	Mean	Range
	Pea Haulm							
Neville		Dookie 1949	Dry Mature	3	2·5	2·4–2·6	38·3	36·6–39·5
,,	Crossbred ..	Walpeup 1949	,,	4	3·1	1·9–3·8	24·0	21·0–32·9
O'Brien	Collegian ..	Walpeup 1951	,,	4	1·3	1·2–1·6		
,,	Collegian ..	Walpeup 1952	,,	5	1·3	1·1–1·7		
,,	McKay ..	Dookie 1952	Green Mature	1	1·7			
Morrison	Unknown ..	America	Hay	35	2·4		17	
			Straw	23	1·0		33	
	Wheat Haulm							
O'Brien	Insignia ..	Walpeup 1951	Dry Mature	8	0·5	0·4–0·7		
,,	Insignia ..	Walpeup 1952	,,	4	0·5	0·4–0·6		

"Haulm" includes leaf and stem but excludes pea pods and seed, or cereal ear.

an occasional hazard to the pea crop in the Mallee. Wheat grain from the 1945 Walpeup harvest was normal in appearance and, as usual, higher in nitrogen than that from Dookie. It was clear that the seasonal conditions were damaging for the pea crop only.

Haulm

The value of the pea plant apart from its grain is considered in terms of nitrogen only, because of the difficulty encountered in estimation of thiamin. The thiamin content is likely to be relevant to the nutrition of non-ruminants but of less value to ruminant species (Blaxter 1954). Table 8 shows nitrogen and fibre determinations on the dry pea plant, excluding the seed, done by Elizabeth Neville and by the Cereal Laboratory of the Department of Agriculture, Victoria. An overseas estimation is added (Morrison 1950) for comparison.

Those from Walpeup wheat and pea plots in 1951 and 1952 can be compared with samples of wheat stubble taken from the same test. The nitrogen level of the pea haulm is nearly three times that of the wheat. The 1952 samples of pea haulm included several with much fungal attack on leaf and stem. The nitrogen level was reduced slightly, but was of the same order as that found in the generally undamaged samples of the previous season.

The sample from Dookie taken from a variety of long growing season, and at the stage just before drying, is of the same level of protein as the best sample of Collegian at Walpeup.

Discussion

The preceding information shows that—

(a) pea grain and haulm are higher in nitrogen and thiamin than wheat grain and stubble, likewise pea grain is higher in thiamin than wheat grain;

(b) environment affects the level of nitrogen and thiamin in pea grain, and of nitrogen in pea haulm;

(d) thiamin is associated with nitrogen and with ash in the variety Dun.

(a) Several lines of research suggest that the high level of nitrogen and thiamin typical of the pea grain is due to a high synthetic capacity and to effective nodulation. Mulder (1948) reported that un-nodulated pea plants died early at low levels of nitrogen supply whereas oat plants produced seed, and at higher levels of nitrogen peas developed a concentration of nitrogen almost 25% higher than that in oats. Bonner and Green (1939) found that peas and tomatoes had a higher thiamin concentration in their leaves than some grasses. McCrae (1943) found that the thiamin level of the green parts of peas at flowering was 5 micrograms per gram, while Geddes and Levine (1942) recorded 3 micrograms per gram in the tiller of wheat at the same stage.

The importance of effective nodulation to protein level has been shown for the soybean by Hampton and Albrecht (1944) and for the peanut by Thornton and Broadbent (1948). In the peanut, the nitrogen of the foliage of nodulated plants was 1.8% compared with 0·9% in un-nodulated ones. That of the fruit was 4·0% and 2·6% respectively. As yet, the relation of nodulation to thiamin concentration has not been reported but it is known that nitrogen supply can affect thiamin concentration in wheat (Greer and Kent 1950) and oats (Hunt *et al.* 1952).

(b) *Grain.* Season affected strongly the nitrogen and thiamin of the grain when seed tissue was damaged by late rains, as in 1945 at Walpeup. However in

the years 1946 to 1949 the only likely relationship between season and these constituents was that of low thiamin and moist spring weather. In cereals, Paull and Anderson (1942) and O'Donnell and Bayfield (1947) have shown an association of weather at flowering time with both protein and thiamin contents of the seed, moist spring weather being connected with high thiamin.

Locality affected both nitrogen and thiamin level. The higher level of nitrogen in the pea at Walpeup in 1946 compared with that at Dookie is typical of wheat grain from these two places. It is likely to be due to the shorter period for seed development at Walpeup. In 1945 the pea grain at Walpeup was lower in nitrogen and thiamin than that of Dookie because of the seed damage in that season. The possibility of such gross damage by late rains suggests the need for rapid harvesting of the pea crop after maturation. The rarity of such damage points to the acceptance of such a risk if the pea crop is more valuable to the farmer as dry grazing material in the paddock than for harvested grain. In 1949, thiamin was higher at Dookie than at Walpeup. Information is needed from other years before it can be seen if this is usual. "High thiamin" areas have been found for wheat in Canada (Johannsen and Rich 1942, McElroy *et al.* 1948), in the United States (Robinson *et al.* 1949) and in England (Greer *et al.* 1952), and it is possible that they might occur for other plant species.

Haulm. The grazing value of the pea haulm depends mainly on its nitrogen and fibre contents at maturation and then on the damage to the tissue by disease or by mechanical means, either of which can reduce the nitrogen in relation to the amount of fibre. In 1949 the higher nitrogen and lower fibre content at Walpeup compared with Dookie is likely to have been the result of careful plant sampling at the former compared with sampling from a raked drilled plot at the latter place. The low estimate by Morrison (1950) of nitrogen in pea straw could be due to mechanical loss of leaf before sampling.

In 1951, four samples of Collegian at Walpeup were damaged by fungal attack on the mature plants following late rains, and one was almost free of it. The latter had the highest nitrogen value but the others were of the same order as the healthy samples from the previous seasons. This suggests that a moderate amount of fungal damage makes little difference to the grazing value of the haulm.

There is overseas evidence of increased level in the haulm of Australian winter peas and vetches with calcium and phosphate fertilizers (Davis and Brewer 1940).

Concerning the effect of variety on the value of pea haulm, it may be concluded provisionally to be of no importance, from the similarity in nitrogen level of the haulm of Mackay, a late flowering variety, and that of Collegian, an early flowering variety. On the other hand, varietal differences in protein level have been found for lucerne (Stuker and Crandall 1953), and the possibility of such should not be ignored for peas.

Evidence that fertilizers can affect the nitrogen content of pea grain (Vidalon *et al.* 1948, nitrogen and calcium fertilizers) and of pea haulm (Davis and Brewer 1940, calcium and phosphate fertilizers) suggests the investigation of nutrient supply in relation to nitrogen and thiamin levels of the field pea grain and haulm.

(c) The occurrence of genetical variation in nitrogen content of the pea grain in the small number of varieties sampled suggests that further testing should be done on other varieties. Weiss, Weber and Williams (1952) found a range of 6% to 7% nitrogen in soybean seeds according to variety. Thiamin estimates should be included on further analyses of pea varieties, as genetical variation in this character has been found for two varieties of peas (Murray 1948) and for

such widely different species as peanuts (Reddi 1949) and wheat (O'Donnell and Bayfield 1941).

(d) The significant correlations of thiamin with nitrogen and ash for the variety Dun at Dookie are the first evidence of such associations in a legume seed. It is interesting to note that Lee and Underwood (1950) found significant positive correlations between nitrogen and thiamin for each of two wheat varieties grown in several districts and seasons in Western Australia. However, research in Canada (Whiteside and Jackson 1943, Spencer and Galgan 1949) showed that this association was affected by variety, as it appears to be with peas. Variation in the correlation of thiamin and ash according to variety of wheat was also found by Robinson and others (1949).

Explanation of both the existence of correlations and of the effect of variety must wait on adequate physiological knowledge of the relationships between these constituents.

From the above discussion it can be concluded that the factors controlling the levels of protein and of thiamin in the pea plant are partly genetic and partly environmental. The high level compared with wheat is likely to be due to a superior capacity for synthesis of both these constituents and to effective nodulation supplying nitrogen for the higher amounts possible in this species.

Detailed investigations on the effect of nodulation, nutrients, season and locality are needed to enable a thorough understanding of the factors affecting protein and thiamin in the pea crop, and so the most efficient maintenance of high levels in these characters.

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Appendix I

Analytical Methods

Estimates on Grain

Each sample of grain was not less than 20 grams (80-100 seeds), to allow for determinations. Each was ground in a Christie and Norris laboratory mill (perforated sheet 1/32 in. diameter, 135/sq. in.). In the resulting flour the epidermis was still visible as small flakes (1 mm. square); the material was thought to be sufficiently finely divided for extraction of soluble materials. Samples were ground when received and stored in airtight containers at room temperature. No deterioration was detected in check samples assayed immediately after grinding and again when the last determinations had been made (up to six months). Eight samples from the Nutrition Laboratory's series, done towards the end of 1946, were checked by Miss Neville in 1950-51 with no difference in result.

Analyses are given on oven dry basis. Moisture was determined by drying at 104° C. to constant weight, ± 0·5%. Nitrogen was estimated by the micro-Kjeldahl method with an error of ± 1%. The factor of 6·25 was used to give crude protein percentage.

Thiamin was estimated by a chemical method, a modification of the thiochrome method of Conner and Straub (1941). Removal of starch and liberation of thiamin from co-carboxylase was carried out by incubating with takadiastase at pH 4·5. Fluorescence in the final solution was read in a Beckman fluorimeter, using a Wratten 49A filter between the solution and photocell. Extraction with 0·06 N HCl at 100° C. was found to be necessary before the enzymatic hydrolysis. The extract showed an intense white fluorescence under ultra-violet irradiation; washing with isobutanol removed material having a blue fluorescence in isobutanol, so that the washed extract had only a small fluorescence within the wavelength range to which the photocell responded. This procedure gave a low blank for unoxidised extracts. However, estimation of the percentage of the true thiamin content obtained by the above procedure (by adding standard thiamin solutions at various concentration levels to the pea-meal at the beginning of the extraction process) suggested that only 85-90% was being recovered. Experiment showed that the fraction lost was adsorbed on the surface of the pea residue remaining after incubation, and that 100% recoveries could be achieved by adding concentrated HCl after incubation to lower the pH to approximately 1 before separation of the extract from the residue. Figures given are averages of three determinations, the standard deviation for the estimation being 1·5/100 units.

Estimations on Haulm

The air-dried material was ground to a fine chaff in the same mill. Nitrogen was estimated as for grain. The thiochrome method was found unsuitable for assaying thiamin in this material; no reliable method could be found for removing interfering substances. Fibre was determined by the A.O.A.C. method.

Appendix II

NITROGEN AND THIAMIN IN PEA GRAIN COMPARED WITH WHEAT

Reference	Material Source and Type	Laboratory	No. of Samples	Nitrogen %		Thiamin %	
				Range	Mean	Range	Mean
Pea Material:							
Haughton ..	Vic., Tas., 1941 Plots and Crops	Melbourne Biochemistry School	8	3·8–5·0	4·2	6·2–13·7	10·2
Coulter ..	Vic., N.S.W., Tas., S.A., 1941 Crops	,,	45			6·4–12·8	8·2
Jones	Vic., Plots 1945	Nutrition Laboratory Adelaide	114	2·7–4·4	3·4		
Jones	Vic., Plots 1946	,,	111	3·4–5·1	4 0		
Neville ..	Vic., 1945 Plots	Melbourne Biochemistry School	7	2·6–3·7	3·0	5·4–8·0	6·1
Neville ..	Vic., 1947–9 ..	,,	60	2·8–4·9	3·7	6·3–13·6	7·2
Snook	W.A. Crops White Brunswick	Depart. Agriculture W.A.	8	3·6–4·1	3·8		
Wheat Material:							
Bottomley ..	Vic. Crop silo delivery samples 1936/7 to 1940/41	Kimpton's Mill Melbourne	250	1·3–2·2			
Aust. Nat. Health & Med. Res.	Aust., Plots 1940/41	Anatomy School Canberra	260+	1·2–2·6	2·0	3·8–6·9	5·3
,,	Plots 1941/42 ..	Biochemistry School Melbourne	45	1·4–2·2	1·7	3·5–6·3	5·0
Finch & Underwood	Vic., W.A., Plots 1949	Agriculture School Perth	49	1·4–2·3	1·8	2·5–5·2	3·9
,,	Dookie, Quadrat 1949	Agriculture School Perth	8	1·7–2·3	2·0	3·4–4·6	3·9
Lee and Underwood	W.A., Plots, 3 Districts, 1949	Agriculture School Perth	50+	1·6–2·1	1·9	3·2–4·1	5·1
Whiteside & Jackson	Western Canada Hard Red Spring Wheats 1940	Whiteside & Jackson	160+	2·2–2·6	2·4	4·0–7·1	5·0

Left: "Bubbly" pea. Section showing floury patch below bubbly area on surface.

Right: "Mottled" wheat. Section through wheat grain showing a similar floury patch under light-coloured area on surface.

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Harris, W. J., B.A., D.Sc., 2 Holden Street, Beaumaris, S.10 1914
Hill, Dorothy, D.Sc., Geology Department, The University of Queensland, Brisbane, Queensland 1939
Hope, G. B., B.M.E., "Carrical," Hermitage Road, Newtown, Geelong 1918
Howe, Mrs. M. A., B.Sc., 18 Devonscourt, South End, Mt. Isa, Queensland 1948
Jenkin, J. J., 35 Marley Street, Sale 1945
Mack, G., B.Sc., Queensland Museum, Brisbane, Queensland 1943
Martin, Miss Gwen J., B.Sc., 101 Waterdale Road, Ivanhoe, N.21 1946
Murphy, H. D., Mornington 1950
Osborne, N., c/o Australasian Petroleum Company, Port Moresby, Papua 1930
Payne, T. E. Neville, "Woodburn," Kilmore 1945
Prentice, H. J., B.Sc., Strangways 1936
Searle, S. S., Metropolitan Farm P.O., Werribee, Vic. 1954
Trebilcock, Lieut.-Col. R. E., M.C., Wellington Street, Kerang 1921
Yates, H., M.Sc., School of Mines, Ballarat 1943

Associate Members

Aitken, Miss Y., M.Agr.Sc., School of Agriculture, The University, Carlton, N.3 .. 1936
Ashton, D. H., B.Sc., Botany Department, The University, Carlton, N.3 1949
Bage, Miss F., O.B.E., M.Sc., Grove Crescent, Toowong, Brisbane, S.W.1, Queensland 1906

Baker, A. A., 52 Carlisle Street, Preston, N.18 1946
Bartlett, A. H., Kent Avenue, Croydon, Vic. 1952
Bell, G., B.Sc., 13 Kent Road, Surrey Hills, E.10 1955
Bishop, J. J., B.A., Northcote High School, St. George's Road, Northcote, N.16 .. 1950
Brazenor, C. W., National Museum, Russell Street, Melbourne, C.1 1931
Broadhurst, E., M.Sc., 457 St. Kilda Road, Melbourne, S.C.2 1930
Burke, Mrs. Lorna M., M.Sc., "Gangara," Hurstbridge 1952
Butcher, A. D., M.Sc., Fisheries and Game Department, 605 Flinders Street, Melbourne, C.1 1936
Butler, L. S. G., No. 3 Los Angeles Court, St. Kilda, S.2 1929
Buttery, S. H., 146 Highfield Road, Camberwell, E.6 1952
Canavan, F., B.Sc., c/o Broken Hill Proprietary Ltd., 422 Little Collins Street, Melbourne, C.1 1936
Carlos, G. C., 262 Tucker Road, East Ormond, S.E.14 1951
Carter, A. A. C., "Fairholm," 15 Threadneedle Street, Balwyn, E.8 1927
Carter, A. N., M.Sc., 70 Madeline Street, Burwood, E.13 1947
Chapman, Brigadier W. D., M.C.E., "Hellas," Stawell Street, Kew, E.4 1927
Chapple, Rev. E. H., The Manse, Warrigal Road, Oakleigh, S.E.12 1919
Clifford, H. T., B.Sc., Botany Department, The University, Carlton, N.3 1949
Clinton, H. F., "Whitehall," 20 Bank Place, Melbourne, C.1 1920
Coats, R. P., B.Sc., Mines Department, Adelaide, South Australia 1951
Cobbett, A. M., Oxford Close, Moorabbin 1951
Cochrane, G. W., M.Sc., Mines Department, Adelaide, South Australia 1945
Collins, A. C., 9 McDonald Avenue, Newtown, Geelong 1928
Condon, M. A., M.Sc., Bureau of Mineral Resources, Melbourne Building, Canberra, A.C.T. 1937
Cook, G. A., M.Sc., B.M.E., 58 Kooyongkoot Road, Hawthorn, E.2 1919
Cookson, Miss I. C., D.Sc., 154 Power Street, Hawthorn, E.2 1919
Court, A. B., Childs Road, Kalorama 1949
Crespin, Miss I., B.A., F.R.M.S., Bureau of Mineral Resources, Melbourne Building, Canberra, A.C.T. 1919
Crohn, P. W., M.Sc., 29 Kensington Road, South Yarra, S.E.1 1946
Currey, D. T., 164 Ormond Road, Elwood, S.3 1948
Dadswell, Mrs. Inez W., M.Sc., 72 Florizel Street, Burwood, E.13 1939
Down, Mrs. Mary R., B.Agr.Sc., 35 Durham Street, Heidelberg, N.22 1942
Dunn, R. A., A.A.A., A.A.I.S., 60 Mimosa Road, Carnegie, S.E.9 1946
Edwards, G. R., B.Sc., High School, Portland 1937
Elford, F. G., B.Sc., B.Ed., 76 New Street, Brighton, S.5 1929
Elford, H. S., B.E., c/o Tait Publishing Company, 349 Collins Street, Melbourne, C.1 1934
Esplan, W. A., 39 Agnes Avenue, Murrumbeena 1951
Essame, J. C. L., B.A. (Camb.), Mines Department, Melbourne, C.2 1951
Fawcett, Miss Stella G. M., M.Sc., Botany Department, The University, Carlton, N.3 1937
Finlay, Miss C. J., B.Sc., Geology Department, University of Melbourne, Carlton, N.3 1950
Fisher, Eileen E., Ph.D., 1 Balwyn Road, Canterbury, E.7 1949
Frostick, A. C., 9 Pentland Street, North Williamstown, W.16 1933
Gaskin, A. J., M.Sc., 1110 White Horse Road, Box Hill, E.11 1941
Gladwell, R. A., 79 Cochrane Street, Elsternwick, S.4 1938
Glenister, B. F., B.Sc., Geology Department, University of Western Australia, Perth, W.A. 1950
Gordon, Alan, B.Sc., c/o C.S.I.R.O., Yarra Bank Road, South Melbourne, S.C.4 .. 1938
Goudie, A. G., B.Agr.Sc., Horticultural Research Station, Tatura 1941
Gunson, Miss Mary, M.Sc., Zoology Department, The University, Carlton, N.3 1944
Hardy, A. D., 24 Studley Avenue, Kew, E.4 1913
Hauser, H. B., M.Sc., Geology Department, The University, Carlton, N.3 1919
Haycraft, J. A., 33 Glenferrie Road, Kew, E.4 1951
Head, W. C. E., 56 Lynch Street, Yarrawonga 1931
Heysen, Mrs. D., P.O. Box 10, Kalangadoo, South Australia 1935
Hill, R. D., D.Sc., Physics Department, University of Illinois, Urbana, Ill., U.S.A. .. 1946
Hogan, T. W., M.Agr.Sc., 25 Devon Street, Box Hill South, E.11 1947
Holland, R. A., 526 Toorak Road, Toorak, S.E.2 1931
Holmes, W. M., M.A., B.Sc., 1 Balmoral Avenue, Kew, E.4 1913
Honman, C. S., B.M.E., 3 Fairy Street, Ivanhoe, N.21 1934

Jack, A. K., M.Sc., 49 Aroona Road, Caulfield, S.E.7 1913
Jessep, A. W., B.Sc., M.Agr.Sc., Botanical Gardens, South Yarra, S.E.1 1927
Jones, D. Spencer, B.Sc., 31 Winmalee Road, Balwyn, E.8 1952
Jones, L. H. P., M.Sc., Ph.D., Chemistry Department, The University, Carlton, N.3 .. 1948
Kenley, P. R., B.Sc., 4 Anthony Street, Ormond, S.E.14 1948
Kenny, J. P. L., B.C.E., 38 College Street, Elsternwick, S.4 1942
Langtry, J. O., 15 Boston Road, Balwyn, E.8 1950
Law, P. G., M.Sc., Antarctic Division, Department of External Affairs, 187 Collins Street, Melbourne, C.1 1946
Learmonth, A. P., B.Sc., Mines Department, Melbourne, C.2 1955
Lindholm, J. D. E., 92 Victoria Street, Carlton, N.3 1952
Lindner, A. W., B.Sc., c/o West Australian Petroleum Pty. Ltd., Box L 898, G.P.O., Perth, W.A. 1949
Lord, E. E., 77a Durham Road, Surrey Hills, E.10 1950
Lynch, D. D., 179 Park Street, Parkville, N.2 1950
McLennan, Assoc. Prof. Ethel, D.Sc., The University, Carlton, N.3 1915
McNally, J., B.Sc., Fisheries and Game Department, 605 Flinders Street, Melbourne, C.3 1950
Macpherson, Miss J. Hope, M.Sc., National Museum, Russell Street, Melbourne, C.1 .. 1940
Manning, N., 733 Punt Road, South Yarra, S.E.1 1940
Marsden, M. A. H., 68 Champion Street, Middle Brighton, S.5 1952
Mitchell, A. W. L., B.Sc., 77 Illawarra Road, Hawthorn, E.2 1946
Mitchell, S. R., 22 Grosvenor Street, Abbotsford, N.9 1945
Morris, P. F., National Herbarium, South Yarra, S.E.1 1921
Moy, A. F., B.A., Melbourne Boys' High School, Forrest Hill, South Yarra, S.E.1 .. 1943
Mushin, Mrs. Rose, M.Sc., Bacteriology Department, The University, Carlton, N.3 .. 1940
Neilson, J. L., 1 Fordham Avenue, Camberwell, E.6 1952
Nye, E. E., College of Pharmacy, 360 Swanston Street, Melbourne, C.1 1932
Oke, C., 34 Bourke Street, Melbourne, C.1 1922
Philip, G. Maxwell, Geology Department, The University, Carlton, N.3 1955
Pike, Miss K. M., B.Sc., Botany Department, The University, Carlton, N.3 1948
Pinches, Mrs. M., 5A Second Avenue, North Williamstown 1943
Pretty, R. B., M.Sc., 62 Glen Iris Road, Glen Iris, S.E.6 1922
Rigby, J. F., Holland Road, Blackburn 1953
Rimington, K. N., B.Sc., 15 Yuille Street, Brighton, S.5 1948
Ringwood, A. E., M.Sc., Geology Department, The University, Carlton, N.3 1954
Rowney, George, B.Sc., 4 Riddle Street, Bentleigh, S.E.14 1952
Schleiger, N. W., B.Sc., B.Ed., 6 Tehan Street, Seymour 1949
Seeger, R. C., 56 Jenkins Street, Northcote, N.16 1946
Shaw, N. J., 192 Victoria Street, West Brunswick, N.12 1950
Sherrard, Mrs. H. M., M.Sc., 43 Robertson Road, Centennial Park, N.S.W. 1918
Shipp, A., "Gangort," Canterbury Road, Heathmont 1946
Singleton, O. P., M.Sc., Geology Department, University of Western Australia, Nedlands, W.A. 1943
Stach, L. W., M.Sc., 78 Herbert Street, Albert Park, S.C.6 1932
Talent, J. A., M.Sc., Geology Department, The University, Carlton, N.3 1955
Thomas, G. A., B.Sc., 39 Duffy Street, Ainslie, Canberra, A.C.T. 1944
Tubb, J. A., M.Sc., Department of Biology, Hong Kong University, Hong Kong . .. 1936
Tugby, D. J., National Museum, Russell Street, Melbourne, C.1 1949
Tylee, A. N., 31 Wingan Avenue, Camberwell, E.6 1951
Vasey, G. H., B.C.E., The University, Carlton, N.3 1936
Watts, H. A., 15 Tower Hill Road, Glen Iris, S.E.6 1954
White, D. A., B.Sc. (W.A.), Bureau of Mineral Resources, Geology and Geophysics, Canberra, A.C.T. 1951
White, Miss Lillian, B.Sc., Royal Merchant Navy College, Bear Wood, Wokingham, Berks., England 1947
White, O. L., Geology Department, The University, Carlton, N.3 1955
Whitehead, Mrs. Sylvia, M.Sc., 48 Invermay Grove, Rosanna 1942
Woodburn, Mrs. Fenton, 21 Bayview Crescent, Black Rock, S.9 1930
Wymond, A. P., M.Sc., Division of Forest Products, C.S.I.R.O., P.O. Box 18, South Melbourne, S.C.4 1951

Royal Society of Victoria

ANNUAL REPORT OF THE COUNCIL FOR THE YEAR 1954

The President and Council present to members of the Society the Annual Report and Statement of Receipts and Expenditure for the year 1954.

The following meetings of the Society were held:

March 11.—Annual Meeting. The following office-bearers were elected: *President*, Dr. F. L. Stillwell; *Vice-Presidents,* Professor E. S. Hills, Mr. V. G. Anderson; *Honorary Treasurer,* Mr. R. T. M. Pescott; *Members of Council,* Mr. L. Adams, Associate-Professor G. W. Leeper, Mr. E. R. Pitt, Dr. D. E. Thomas.

The following *Members of Council* continued in office: Mr. W. Baragwanath, Mr. D. A. Casey, Capt. J. K. Davis, Professor O. W. Tiegs, Professor J. S. Turner, Professor S. M. Wadham.

The Annual Report and Financial Statement for 1953 were read and adopted. At the close of the Annual Meeting an Ordinary Meeting was held. Lecture: "The Egyptian Scene", by Professor E. S. Hills.

April 8.—Paper: "Newer Volcanic Vents and Lava Fields between Wallan and Yuroke, Victoria", by W. Hanks. Lecture: "Vegetation and Scenery of New Zealand", by Professor J. S. Turner.

May 13.—The following office-bearers were elected to fill vacancies remaining after the Annual Meeting: *Honorary Librarian,* Associate-Professor C. M. Tattam; *Honorary Secretary,* Dr. K. Washington Gray; *Members of Council,* Mr. J. H. Chinner, Mr. P. Crosbie Morrison. Lecture: "The 1954 Expedition to MacRobertson Land", by Mr. P. G. Law.

June 10.—Papers: "Cactus Canker caused by *Botrytis cinerea* Pers.", by Eileen E. Fisher (read by title only); "Geology of the Deddick-Wulgulmerang Area, East Gippsland", by A. E. Ringwood; "Geology of the Snowy River District, East Gippsland", by A. E. Ringwood.

July 8.—Papers: "The Stratigraphy of the Tertiary Rocks between Torquay and Eastern View, Victoria", by H. G. Raggatt and Irene Crespin; "Petrography of the Sedimentary Rocks from the Torquay-Eastern View Area, Victoria", by W. B. Dallwitz (read by title only); "Petrographical Study of Rock Samples from the Coastal Section between Torquay and Airey's Inlet, Victoria", by J. E. Glover (read by title only).

August 12.—Lecture: "Water—and Australia", by Dr. S. N. Bastow.

September 9.—Lecture: "Defence Science in Australia, and the Woomera Rocket Range", by Mr. W. A. S. Butement.

October 14.—Lecture: "Science and National Development", by Sir Ian Clunies Ross.

November 11.—Paper: "Curvature—Size Relationships of Port Campbell Australites, Victoria", by George Baker.

December 9.—Professors S. M. Wadham and J. S. Turner were elected Honorary Auditors. Papers: "Comparison of the Actual Tides of Hobson's Bay with those predicted from Harmonic Constants", by J. E. Bradley (read by title only); "The Range and Distribution of *Diprotodon minor* Huxley", by Edmund D. Gill; "A Preliminary Revision of the families Patellidae and Acmaeidae in Australia" by J. Hope Macpherson; "Influence of Environment and Variety on Nitrogen and Thiamin in Field Peas (*Pisum sativum*)", by Yvonne Aitken.

During the year eight Members, two Country Members and two Associates were elected. One Member, one Country Member and one Associate resigned. The total membership of the Society on December 31, 1954, was 255.

The Council deeply regrets the loss by death of one Life Member, two Members and two Country Members.

James Gerald Roy Felstead, M.D., F.R.A.C.S., was born at Christchurch, New Zealand, on February 5, 1887, and died in Melbourne, Victoria, on January 26, 1954. He was educated at St. Paul's Cathedral School, Wesley College, and the University of Melbourne. After graduating M.B., B.S., with honours in 1909, Dr. Felstead served as a resident medical officer at the Melbourne Hospital and at the Women's Hospital in Melbourne before taking up practice first at Nhill, and later at Horsham where he founded a well-equipped clinic and became widely known and respected throughout western and north-western Victoria. At the time of his death he was honorary consulting surgeon to the Wimmera Base Hospital and a Life Governor. He was elected a Country Member of the Society in 1945.

Edward Leslie Gault, M.A., M.B., B.S., died at Warrandyte, Victoria, on December 18, 1954, at the age of 92. He was one of Melbourne's pioneer eye specialists, and practised for many years in Collins Street. After a period of service as a house surgeon at the Moorfields Eye Hospital in London he returned to Melbourne and established the eye clinic at the Alfred Hospital. Dr. Gault became a Life Member of the Society in 1936, having been elected a member in 1899, and was a member of the Council of Wesley College and of Queen's College. He was one of the founders of an organization at the University which was the fore-runner of the Australian Student Christian Movement.

Leslie James McConnan, Kt., was born at Benalla in 1887 and died in Melbourne on December 22, 1954. Educated at North-Eastern College, Benalla, he joined the local branch of the National Bank at the age of 17 and became Chief Manager of the Bank at the age of 47. He was three times Chairman of the Associated Banks of Victoria between 1938 and 1949. He was knighted for public services in 1951. He was for many years a member of the committee of management of the Royal Melbourne Hospital, the Council of the Australian Red Cross, the Council of Geelong College and the Council for Christian Education in Schools, and was President of the Banks Rowing Club and Chairman of the Baby Health Centres Movement. He was elected a Member of the Society in 1951 and was appointed a Trustee in January, 1952.

Samuel Furneaux Mann died on July 21, 1954, at the age of 88. He was a well-known Victorian grazier and had been owner for many years of

Laurenny Station near Caramut. Distinguished in his youth at Geelong Grammar School, and later, as an oarsman and all-round sportsman, he had always shown great interest in trees, flowers and birds, and had presented a collection of aboriginal implements to the National Museum. He was elected a Country Member of the Society in 1922.

Douglas John Thomas, M.D., M.R.C.P. (London), F.R.A.C.P., was born at Bairnsdale on February 6, 1896, and died at Olinda on January 11, 1954. He was educated at Grenville College, Ballarat, Wesley College, and Queen's College in the University of Melbourne. Dr. Thomas, a consulting physician practising in Collins Street, was for many years a member of the staff of the Royal Melbourne Hospital, which he joined in 1919, and had served in both World Wars. He was a Colonel in the Australian Army Medical Corps (Reserve), a member of the War Assessment Appeals Tribunal, a Trustee of the Medical Society of Victoria and had been in charge of the Australian General Hospital at Heidelberg. He was the author of a number of papers on medical and radiological subjects, President of the British Medical Association (Victorian Branch) in 1949, and formerly Lecturer and Tutor in Medicine at Queen's College. He was elected a Member of the Society in 1924.

Attendances at Council meetings were as follows: Mr. Adams, 7; Mr. Anderson, 9; Mr. Baragwanath, 3; Mr. Casey, 9; Mr. Chinner, 4; Capt. Davis, 10; Dr. Gray, 7; Professor Hills, 6; Associate-Professor Leeper, 7; Mr. Crosbie Morrison, 6; Mr. Pescott, 9; Mr. Pitt, 8; Dr. Stillwell, 11; Associate-Professor Tattam, 11; Dr. Thomas, 7; Professor Turner, 4; Professor Wadham, 2. Professor Tiegs was unable to attend Council meetings because of absence abroad.

During the year 2,016 volumes and parts were added to the Library. Operation of the Library was resumed during the year but a great deal of work has been involved in the reorganization, and still continues.

After completion of the extension, redecoration and refurnishing, the Society's Building was formally re-opened on August 25, by The Lieutenant-Governor of Victoria, Lieutenant-General Sir Edmund Herring, and the Royal College of Obstetricians and Gynaecologists then entered into joint occupancy. The Society and the College were represented by their respective Presidents in the opening ceremony. Under agreements between the Society's Trustees, the Arthur Wilson Memorial Foundation, and the Royal College of Obstetricians and Gynaecologists, the latter is to have exclusive use for the period of the lease of certain portions of the new part of the Building for its Australasian Headquarters, and joint use, with the Society, of the Lecture Theatre, Library Room and Supper Room. The Society resumed use of the Lecture Theatre in April. Since the formal opening the Arthur Wilson Memorial Foundation has completed reconstruction of the grounds, which are in future to be maintained by the Melbourne City Council. Council records its appreciation of the improvement in the building, and the achievement of the architect, Mr. H. J. Heath, in maintaining the character of the old building in its enlarged form.

Gifts from donors have been gratefully received by the Society during the year as follows: New Projector Screen for the Lecture Theatre—Mr. S. W. Gadsden. Printing of new edition of the Laws—Containers Ltd. Electric floor-polishing machine from a donor who wishes to remain anonymous. Contribution to the cost of transfer cases for the Library—Imperial Chemical Industries of Australia and New Zealand Ltd.

HONORARY TREASURER'S REPORT

The year just completed has seen considerable changes in the Royal Society Buildings which have entailed considerable expenditure.

Although the credit balance of £139.16.1 at December 31 compares unfavourably with that of £778.1.9 at January 1, there are several factors responsible for this:

(a) the expenditure of £1,041.10.0 on printing of the Proceedings was considerably greater than normal, being the cost of one and a half volumes, Vol. 65 part II and Volume 66.

(b) the expenditure of £492.2.9 on repairs to the caretaker's cottage, some of which were considerably overdue; and

(c) the expenditure of £236.5.0 on steel shelving for the library.

The increasing of the subscriptions from the beginning of 1954 has had little effect on membership. Members are again reminded that subscriptions become due on January 1 of each year, and in order that the affairs of the Society proceed smoothly they should be paid promptly. During the year, a fixed deposit of £200 matured, and your Council decided not to renew this, but to transfer the proceeds (£207) to the current account.

The Society again expresses its appreciation of the action of the State Government in maintaining its annual grant to the Society at the figure of £500.

FINANCIAL STATEMENT FOR YEAR ENDING DECEMBER 31, 1954

RECEIPTS

Balance in Bank at 1/1/1954		£778 1 9
Subscriptions—		
Members	£272 9 6	
Associate Members	165 18 0	
Country Members	36 15 0	
Arrears paid up	64 1 0	
Advance Subscriptions	2 2 0	
		541 5 6
Rents—		
Commonwealth Government	104 0 0	
Field Naturalists Club	16 0 0	
		120 0 0
Sale of Publications		43 9 9
Interest on Bonds		14 5 0
Grants and Donations—		
State Government	500 0 0	
University	147 6 0	
		647 6 0
Transfer of Fixed Deposit to Current Account		207 0 0
Sundries		9 2
		£2,351 17 2

EXPENDITURE

Salaries—			
Assistant Secretary		£30 0 0	
Assistant Editor		45 0 0	
Hallkeeper		39 3 0	
Gardener		3 10 0	
			£117 13 0
Printing—			
Proceedings:			
Vol. 65, Part II	£396 10 0		
Vol. 66	645 0 0		
		1,041 10 0	
General		17 10 0	
			1,059 0 0
Light, Water and Gas			53 0 8
Telephone			32 0 6
Rates and Taxes			53 4 11
Petty Cash			17 3 1
Postage			58 18 8
Meetings			17 16 6
Repairs			492 2 9
Insurance			48 2 0
Fire Brigade			1 5 0
Steel Shelving			236 5 0
Purchase of Lantern			22 10 0
Sundries			2 19 0
Balance in Bank at 31/12/1954			139 16 1
			£2,351 17 2

R. T. M. PESCOTT, *Hon. Treasurer.*

Audited and found correct
February 25, 1955.

S. M. WADHAM }
J. S. TURNER } *Hon. Auditors.*

SPECIAL FUNDS

HALL FUND

Balance at 1/1/1954	£74 12 4	Balance at 31/12/1954	£76 5 8
Savings Bank Interest to 31/5/1954	1 13 4		
	£76 5 8		£76 5 8

LIFE MEMBERSHIP FUND

Balance at 1/1/1954	£186 8 2	Balance at 31/12/1954	£190 11 10
Savings Bank Interest to 31/5/1954	4 3 8		
	£190 11 10		£190 11 10

HOWITT MEMORIAL FUND

Balance at 1/1/1954	£143 8 7	Balance at 31/12/1954	£154 7 10
Interest on Bond	7 15 0		
Savings Bank Interest to 31/5/1954	3 4 3		
	£154 7 10		£154 7 10

R. T. M. PESCOTT, *Hon. Treasurer.*

Audited and found correct
February 25, 1955.

S. M. WADHAM } *Hon.*
J. S. TURNER } *Auditors.*

SPECIAL FUNDS

T. S. HALL MEMORIAL FUND

Balance at 1/1/1954	£85 6 0		
Savings Bank Interest to 31/12/1954	1 18 3	Balance at 31/12/1954	£87 4 3
	£87 4 3		£87 4 3

BOOK-BINDING FUND

Balance at 1/1/1954	£122 1 1	Balance at 31/12/1954	£124 16 0
Savings Bank Interest to 31/5/1954	2 14 11		
	£124 16 0		£124 16 0

Accounts and Pass Books relating to each of the above Funds have been severally examined and found correct, and the Bank receipts of possession of Bonds amounting to five hundred pounds (£500) and Savings Certificates to the face value of two hundred and fifty pounds (£250) have been inspected. Of the Bonds, one hundred pounds are to the credit of the Howitt Memorial Fund.

R. T. M. PESCOTT, *Hon. Treasurer.*

Audited and found correct,
February 25, 1955.

S. M. WADHAM } *Hon.*
J. S. TURNER } *Auditors.*